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Proofs and illustrations of
the attributes of God

PROOFS AND ILLUSTRATIONS
OF THE
ATTRIBUTES OF GOD,
FROM THE FACTS AND LAWS OF
THE PHYSICAL UNIVERSE:
BEING THE FOUNDATION OF
NATURAL AND REVEALED RELIGION.

BY JOHN MACCULLOCH, M.D.,

F.R.S., F.L.S., F.G.S., &c. &c.

“The invisible things of Him from the creation of the world are clearly seen, being understood by the things that are made, even his eternal power and Godhead.”—ROMANS, i. 20.

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CONTENTS

OF

THE SECOND VOLUME.

DIVISION IV.

OF THE POWER OF THE DEITY.

CHAPTER	PAGE
XXIV. Of the Power of the Deity. Omnipotence . . .	3
XXV. On the Variety in the Animal Creation . . .	13
XXVI. On the Variety in Plants and Minerals. Clean- liness of Creation	55
XXVII. On the Light of the Marine Animals . . .	80
XXVIII. On the Modes of Motion in Animals . . .	91
XXIX. On the Organized Structures in Animals and Plants	124
XXX. On Muscles and on Muscular Motion . . .	193
XXXI. On the Involuntary and Unconscious Muscular Actions, and on certain modes of Sensation . . .	221
XXXII. On Water	250
XXXIII. On the Atmosphere	275
XXXIV. On Electricity and Magnetism	303
XXXV. On Heat	319
XXXVI. On Light	352
XXXVII. On Chemistry	388
XXXVIII. On the Mechanical Properties of Matter . . .	431
XXXIX. On the Celestial Mechanism	469

ERRATA IN VOLUME THE SECOND.

- Page 51, line 12, *for* "cilici," *read* "cilia."
" 67, " 5, *for* "alone," *read* "also."
" 70, " 25, *for* "render," *read* "renders."
" 77, " 15, *for* "Trigonellaa," *read* "Trigonella."
" 234, " 27, *for* "case," *read* "cause."
" 264, " 6, *for* "It is," *read* "Is it."
" 495, " 28, *for* "opposite," *read* "apposite."

DIVISION IV.

OF THE

POWER OF THE DEITY.

OMNIPOTENCE.

&c. &c.



PROOFS AND ILLUSTRATIONS
OF
THE ATTRIBUTES OF GOD;
§c. §c.

CHAPTER XXIV.

OF THE POWER OF THE DEITY. OMNIPOTENCE.

IF the meaning of Omnipotence is obvious, yet is this among the difficult questions respecting the attributes of the Deity, which have been much discussed by metaphysicians; and frequently, under a purposeless length: since it is not easy to see what is gained by accumulating words, and varying phrases, on subjects beyond the bounds of our intellect. I neither intend to repeat all that they have written, or to examine it. As to this class of investigations, my purpose, throughout, has been limited: and for those who desire to read more, the writers are as abundant as they are accessible.

The Power of the Deity is a proposition so necessarily consequent on the acknowledgment of Him as the Creator of the Universe, that it may rank in the class of self-evident truths: it would be a waste of words to deduce it, as has often been done, through a more circuitous phraseology. But it is by no means so easy to infer His entire and absolute power, or omnipotence: from

an essential difficulty in the very nature of the term, as it might be applied. It is a quality not well definable, under all the possible applications of this not very convenient term. Some theologians have therefore escaped from the difficulty, by evading it. It has thus been termed a power greater than any which we experience in ourselves or in any other known agents ; to which we are not authorized to assign any limits. Others have proceeded much further ; thus, often encumbering their discussions with appeals to other attributes of the Deity, and, even then, leaving unsolved the difficulties which those inquiries, thus pushed beyond our powers, have brought forth in a stronger light. And some of these at least, I am bound to notice.

It is identical, and therefore useless, to argue the perfect, or entire Power of the Deity, from His Perfection. Of its absoluteness in the physical world, we can only judge from what we see : while thence we can merely conclude, that He could perform much, or greatly, or infinitely more of what He has already effected, and also that He possesses the absolute power over all that which He has appointed. On the same grounds, we admit that he could change or rescind any of His plans or laws : but of what else He might do, we can form no conception : as we have no means of speculating but from what He has done. His physical Omnipotence remains therefore a vague word, to which we can attach no definite idea. In this case also, it must be conceded that even His unbounded power could not produce contradictions ; though inconsiderate reasoners have attempted to deduce even this, from a loose application of the term Omnipotence. A contradiction is no other than a nullity ; this would be to will nothing : so that the propo-

sition itself is a null one, devoid of meaning. The answer is abundantly simple.

But the greater difficulty respecting the omnipotence, or boundless power of the Deity, relates to the moral world : and it has been argued under different views. This difficulty consists in the existence of evil, under absolute goodness and absolute power. How far those disputes have led, I need not say : especially as this question will also occur hereafter. But it has been suggested in explanation, that there are moral impossibilities, as well as physical ones, while they are of a nature which we cannot discern ; so that although we were to conceive that power limited, in the moral world, or short of Omnipotence, in the perfect sense of that term, it would be no more than to say, in the physical world, that the Deity could not produce contradictions ; and for the same reason, that this is a nullity. Attempts also have been made to surmount this difficulty, under the doctrine of the Free-will of man : or, it has been inferred, that in this case, and for obvious purposes, God has divested Himself of a portion of His power ; which, to resume, though in that power of course, would be contradictory conduct, and therefore not to be found in Him.

That no length of discussion has ever made this subject plainer, is most certain : while it is equally true, that the metaphysical theologians have, reversely, obscured and encumbered it. To avoid it therefore, is not less right than convenient, from the moment that it passes beyond the reach of our faculties. To do this, is that plain confession of ignorance which we are always unwilling to make ; sometimes, from a laudable principle, but more frequently, it is to be feared, from vanity.

On the moral nature, or quality, of the power of the Deity, much has also been said by theologians. But these discussions involve the consideration of others of His attributes, namely, His justice, wisdom, and goodness. I do not perceive that any of those statements are required for the objects of this work, or that they are even relevant to its restricted and peculiar views. The purpose, here, as elsewhere, is to give proofs or illustrations of those attributes with which the physical creation is concerned, or which can be displayed through that department of the universe. And it is, therefore, Power which is to be evinced or rendered tangible, not Omnipotence which is to be argued. It is the business of metaphysics to infer the ultimate, or infinite, as they best can ; and I have perhaps sufficiently indicated what they have attempted, and almost also, what they have done. For those who desire to read more largely on the moral nature of God's power, it is best to refer ; and most convenient, perhaps to refer to Clarke. As far as this concerns the limitations of His omnipotence, it will be there found, that the difficulty is set aside by the broad consideration, that all His attributes are inseparable ; that all is One, Himself. Or otherwise, that as far as any attribute is to be supposed limited, the limitation is a necessary part of His nature : yet in this sense alone necessary, that to assume the contrary would become a contradiction in terms, or a nullity. This is the result : the details can be read in that writer, and in many more : if they do not very visibly explain this conclusion.

But the following remarks, slight as they must necessarily be, will probably possess more interest for the readers of this work ; since they more nearly meet the

difficulty which we all feel in trying to conceive in what manner God, or His power, acts in the physical universe, in the production of all the effects known to us. For difficulty, indeed, I might have substituted the word impossibility : since we are not merely unable to view the universal and truly incredible power of the Deity in a just light, but do not find it easy, even to turn our thoughts on the manner in which it produces its endless effects, because we have scarcely a ground of comparison in our own conduct and experience, or in that, from which alone we can ever form an intelligible judgment respecting Him.

Yet there are two modes of viewing this subject, which may at least assist the imagination : as that is all which we can ever hope to do in such a case. If we consider the Deity in the light of a Mechanic and a Chemist, knowing that the whole physical universe is governed by mechanics and chemistry, we can perceive this. The human artist, in each, is limited, first, by his knowledge of the existing materials required for the execution of a work in either, or each, department ; again by his mere deficiency of power, or by the confined number and quantity of the things which he can command, or reach and dispose of ; still further, by time ; and, last of all, by magnitude : these materials ceasing to be objects of sense to him, beneath a certain point, as, beyond another point, they are utterly out of his grasp, if cognizable by some of his senses. Now, the Deity is, in all this, unlimited : and therefore, were He viewed as a merely human artist, operating only through the same powers as He has granted to us in a limited degree, He could effect all these things, as He actually does ; even did we take an anthropomorphous view, in

every sense except that of his universal presence, and suppose Him operating, as man does, by hands. But we can readily grant, also, that it is as easy for Him, and as sufficient, to say the word, or to will all these motions of materials, known to Him and present to Him, as it is for the human spirit to will the motions of the materials placed in its power, through the intervention of muscular force, which is but an intermedium between the human will and those effects; as, between that human will, and muscular action, there is an unknown chasm. Rather, to speak with more physiological accuracy, this chasm takes place between spirit and the material, if unknown, nervous power: yet it is an equal one, since it is that action of mind on matter, through will, which remains, and ever will remain, the inexplicable mystery of Creation. There is no greater difficulty then, difficult as all is, in conceiving that the Divine Will can, and does, move all the materials of the universe, by a simple and direct action; since this is but to do, universally, and, at the same time, in a shorter way, what He has empowered man to do, to a narrow extent, and by a more circuitous road. Or if, still further to aid the imagination, we borrow an hypothesis from an ancient philosophy, we may suppose that matter, in all its forms, is the body of the Deity, which is therefore acted on directly by His spirit, in whatever manner that desires.

This is the most tangible and simple illustration of the mode of power in the Deity; as it leaves that power, in the case of the physical universe, without conceivable limits. But for those who prefer metaphysical views of such subjects, I may offer this mode of contemplating the same question. There is nothing, of any nature, be it

matter, or motion, or spirit, or whatever else, if more there be, but what exists through Him or in Him; and all this, consequently, is, metaphysically, Himself; or, under a similar fiction, in aid of the imagination, all these are parts, or properties of the Deity, as the Great Existence. If therefore He is, in any one manner, He may be, in any other: while to be thus, is to be, or to do, anything: or it is to permit Him, simply, all power over Himself, and thus to allow Him all power over the universe. And, metaphysical as this view may be, it is also conceivable, on the same grounds as before: because we also feel, or believe, that we have similar power over ourselves, as far as we have been allowed to possess any.

It is so desirable to aid these conceptions respecting the nature and action of the Power of the Deity, that I may be excused for stating the same thing, once more, in another manner; since there are readers who might find difficulty in one of those views, and repugnance to the other. If He caused, and causes, the existence of matter in any one manner, He can equally cause that in any other, or can change its mode of existence, at any moment. But, in reality, matter, constituting the materials of the universe, is not a mere existence, produced once, and for ever, under rest or in action. There are various materials, or modes of matter, with powers, or qualities, and with different places, and motions, and actions on each other; and thus were they all created, or appointed. His will, or hand, to repeat that metaphor, produced them all under those circumstances, and produces, or changes them constantly, in the same manner: which, if He did not, He would be the inactive Deity of the Aristotelian philosophy. It is, there-

fore, a purely identical proposition to say, that the Creator of the universe must possess a power over matter, and all its motions, of whatever nature, as unbounded as that through which He did originally create or appoint that universe : since these two are, even physically, the same thing.

I have already remarked, that the object of this work is, to illustrate the attributes, simply, wherever it was superfluous to prove them. And such is the purpose of the following chapters. It is to display the exercise, and to impress the conviction of Power : if for many other reasons, for this also, that in contemplating difficulty and darkness and mystery, in the exercise of wonder and admiration, the higher energies of the mind are roused, and it is thus led to reflect more intensely on the great mysterious Cause of all. And the demonstrations of this attribute being among the most numerous and unquestionable, it is a division therefore which ranges through a considerable variety of the objects of Creation : of which, also, many can be brought to bear on this attribute, which are not so easily or conveniently applicable to any other. We can discern power without difficulty, where we cannot always trace design, or wisdom, or goodness : the former requires little more than the exercise of observation ; the others call for much knowledge, both physical and moral, and often, for considerably acute and careful reasoning.

I have attempted to display power in some of those cases, by comparing that which appears, with our own. This is a simple method, as it is also the most striking : while it is sufficient barely to know the facts. But there are other instances, where no such comparison can be made : because we do not know how the effect

is produced, and cannot imitate it. The appeal, here, is made to our ignorance, instead of to our knowledge : it is the incomprehensible of power. And when, to all our modes of conception, the execution was impossible, while we nevertheless see that the fact exists, our notion of a power infinitely exceeding our own, is carried as far as it can be. I have not pointed out our ignorance for the purpose of exposing it, but that it may be used as a measure, or point of reference, for the power of the Deity. And thence the disputes, and obscurities, and hypotheses of philosophy are rated under its ignorance. It is sufficient, here, that such things are not known : while this is not the place to discuss the probabilities of theories. It was my business to proceed immediately to the Deity, from the point at which man stops : let him attain, hereafter, to what knowledge he may, the Power will still remain, though we may then gain a nearer insight into the mode in which it operates.

If the very great, the enormous power of the Deity, is here sometimes urged, from a comparison with the feebleness and littleness of man, if his insignificance in the inappreciable extent of Creation is pointed out, it is, still, for the purpose of comparison, not with a design to debase him. Man himself is a great effort of power : the more extraordinary that Power which could perform so much more. The nations of the world are as dust in the balance : but the poet intended to magnify God, to whom even nations could be as that dust which is unfelt. Yet, nevertheless, He is "mindful" of man. This is to understand our just relations to Him. The lesson which natural history conveys, from the extent and the population of the unbounded universe, is not a lesson of despair. The same argument which had de-

pressed us, serves to elevate us again, when it is justly contemplated. When man looks above, at the boundless heaven of orbs and their incomputable inhabitants, he shrinks before the thought : when he inspects the myriads, of incalculable smallness and utter apparent insignificance, beneath, he rises again : secure, that He who thinks for them, as He created them, thinks also for him ; thinks and cares for all. But I have fallen, unawares, into the argument used by the highest authority which we have known on earth. That He appealed to natural history, is a warranty for the choice here made : that His arguments were those of Natural Religion, ought to prove that He thought this study worthy of man, when He thought it not beneath Himself.

CHAPTER XXV.

ON THE VARIETY IN THE ANIMAL CREATION.

I HAVE commenced the present division with two sketches indicative of the variety, which is found in the works of creation ; since, in displaying invention and resource, it is the evidence of Power. Invention alone is power : and it is also power, to have compassed the same ends in many different modes. The inventive powers of man are not, simply, limited : it is difficult to prove that he possesses aught but the talent of varying that which has been invented by the Creator, or of recombining those inventions into new groups ; being thus, in reality, but a copyist. He has often attempted to design new animals ; but they have ever been compounded from the parts of known ones : while, where his novelties have been greatest, the anatomist has not been able to supply the parts necessary to motion. No botanist invents a new plant but in the same manner ; yet he receives from nature a hundred new inventions without the least surprise. The designer of ornaments must have recourse to the same inexhaustible source ; and when he attempts to improve, he soon finds that he is compelled to return to his model and teacher. Be the painter what he may in poetic talent, he is but the transcriber of what nature has produced, as his excellence consists in selection and adaptation. The Poet, equally,

notwithstanding the prejudices in favour of his invention, is the recorder and combiner of what exists, while even his abstractions are but analyses of nature. There is but one inventor: it is the Omnipotent who has invented all things.

The inventions of man appear numerous to an uninformed and superficial judgment; but their limitation is, in reality, very narrow: he displays very little resource in the means of compassing his ends. He modifies or combines the mechanical or other principles and the materials which the Creator has appointed; but he cannot strike out a new path for himself, as he never invented a principle. Every one of these has been already applied; he can only borrow: while, when he imagines that he has discovered a novelty of his own, he will find that nature had anticipated him: presuming him to forget that he could possess nothing but what he had received from his Creator. We should be ready to correct the bee, should it say that it had invented its own geometric rule; but we forget that whether He communicates His knowledge through what we are pleased to term instinct, or through the more laborious road of observation and reasoning, it is equally of His gift. Man is also well pleased to gain his ends in one manner, and in the easiest: he has no power to waste, and no superabundance of resource to expend on superfluity.

Variety of invention and of resource being thus, to us, evidences, or modes, of the power of the Omnipotent, whatever purposes they may have had, it remains to ask respecting His intentions in that display of both which creation affords. There is a dogma, of universal reception, that everything in the world was created for some

use, whether we can discover that or not ; as the term use, in this case, means utility. And there is another dogma, equally received by philosophers, and which I have but recently noticed (c. 23), namely, that the Creator effects all His ends in the simplest and easiest manner. If both those dogmas were true, there could be no such view as the one here proposed : these sketches would be untruths. It is therefore needful to commence by examining each of them.

It is of the Creator's power to combine utility with all else ; or He may have attached some utility to every material or object which He has created ; but it does not follow that every circumstance in every material, or every part and property of every object is useful, or was intended for use, or that every separate object has its distinct utility. The facts will abundantly evince the reverse, or show that this is not the sole intention in Creation. Utility is indeed beneficence ; but it is the character of the beneficence of the Deity to have created for pleasure also ; and this is superfluity, not use. We shall immediately see whether He has not had other motives than both these : but in the mean time, this dogma takes a false as well as a debasing view of the Creator. To the other one, it must be granted that it is of His wisdom to execute everything in the best manner ; but that wisdom is not His only attribute. He possesses others, and He unites the demonstrations of more than one. There may be superfluity, as His wisdom alone is concerned ; which therefore, a quibbling and not pious logic might term unwise, seeing that He has, for example, not taken the simplest road to His end. But such proceeding is not superfluous, when it is the effect of His beneficence ; nor is it such, if it has

been intended to display the resources of His boundless mind. It is plain therefore, that both these popular dogmas proceed on a false *à priori* view of the character of the Deity. They are also both nullified, I trust, by these more just metaphysical and theological inferences ; while they will be fully disproved by the facts of creation. And a few of those facts may be stated, as a condensed answer to each, before proceeding to the following sketches, from which the reader may add abundance more.

As far as the hypothesis of universal utility is concerned, very little will suffice. There are many hundred forms of calcareous spar ; but there is no more use, actual or conceivable, in the whole, than in one, or in common limestone : while the same remark may be extended to varieties in the metallic ores, and, much more strongly, to the endless crystallized earthy minerals, which are totally without utility. Scarcely anything indeed in this division of nature is of use to any animal ; while, to man, they are superfluities, efforts of invention for his sake ; in whatever manner he may derive pleasure or instruction from them. In the vegetable world, a single flower would be an answer to this dogma : the neutral floret of Centaury is without even an attached use : it is a pure superfluity. But the splendour, the variety, and the beauty, in this department of creation, form an overwhelming answer : it is an entire system of superfluity, of prodigality of invention, whatever uses may be combined with all this “ waste ” of power ; as is not always the fact. The colours of the Tulip and the Poppy, the nectary, as it is termed, of the Passion-flower, the petals which afford no protection, the odours of the Jessamine and the Rose, all colours, all variety of forms, all odours,

must have been rejected on the exclusive principle of utility : a mere calyx might have performed the necessary duties for every flower, as it does for many.

It is the same in the animal world. To what end the stag's horn, when the utility is confined to the least of its branches ? The peacock's tail is not merely useless, it is an encumbrance to the flight of the animal. One or two species of humming-birds would have sufficed to consume all the food prepared for this tribe ; the present number is of no use ; and of still less, is all their variety and splendour of colouring. The painted shells abound in beauties which no one but man can see, not even attaining to do that without much labour : for all ends, the *Pecten* need not have been painted scarlet or yellow ; and the pearl oyster might have existed for all its uses, under an ordinary shell. The coral animals need not have formed hundreds of their own beautiful and diversified plants : a few forms would have furnished dwellings for all, and a few would have sufficed to construct the great works which they execute. . Everywhere in the animal kingdom there is the same superfluity of invention, of beauty, ornament, inutility, as in the vegetable world. The uses indeed are united to all this ; but those would remain though the greater part of the inventions were struck off. The painting of the feather conduces nothing to the support of the animal in the air : if used for distinctions, for mutual recognition among the species, as it undoubtedly is, it did not require all the stars of the peacock or the *Argus* pheasant to have gained this end. It is as well attained with far less invention in the lark and the thrush.

And the reasoning is the same as it relates to the variety in the forms, or species of animals. It may be

true that this variety aids in the replenishment of the earth, as I have elsewhere shown. But there are abundant exceptions: the whale, destroying millions of shrimps every day, does not aid in making the earth fuller of life. Nor were all these species necessary for preserving the balance of creation; since I have also shown (c. 54), that it admits of innumerable balances. In this variety, equally, there is prodigality of invention, without use: and I need not apply these remarks to the vegetable species, where it is not less true. There is indeed utility; but it is not that which this popular opinion contemplates. All things are useful which teach us to know the Creator.

With respect to the other dogma, it is far from true that nature takes the shortest and easiest roads to her ends, that she employs the least possible power, and that she is ever consistent in her conduct: on the contrary, it is opposed by the far greater number of the facts in natural history; as I have already partially shown in the 23rd chapter, under what is termed natural philosophy. It would be much more true to reverse the assertion, and to say that it was nature's intention to show in how many different modes she could attain her ends; that so far from being economical, she was prodigal, even wasteful of means, of power, of materials, of everything; wantoning, I may say, in variety and wastefulness, as if to prove her boundless and inexhaustible resources. The slightest glance at the earth must show, that this, and not the reverse, is the proceeding of the Creator of "nature;" to whom neither economy of invention or power was necessary, whatever other evidences of economy may appear on another subject which I shall notice in a future place.

This maxim of economy, falsely deduced from a single set of facts, may be true in dynamics, as there are evident reasons why it should there be the rule of proceeding: it is sometimes even reducible to an identical proposition. But the mathematicians who have maintained it, have forgotten that it is not even true of the solar system, regarded as an object of natural history; since we see even there, the same demonstration of invention, variety, or we may say, superfluity. Why else does Saturn possess a ring, when Uranus is aided by moons only? there is no other answer but that which I have suggested. Astronomers may ask the same question respecting the double systems of circulating suns: nor can we decide what other varieties of this high mechanism may not be contained in the unbounded universe.

But this is infinitely more remarkable in the organized creations, where the scope for variety of invention was incalculably greater. In the vegetable world, there is a certain end to be attained by a contrivance; it was required that the feeble and prolonged plants should support themselves above the earth. Philosophy must determine which would have been the most simple and economical mode; but we find hooks, in the Galium under one form, in the Bramble under another, voluble stems as in the Hop, voluble leaves in Fumitory, tendrils in the Vine, claws in one Ivy, radicles in another, and still more in the creepers of the hot climates. It was one of the Creator's ends to disperse the seeds of some plants: we formerly (c. 10) saw the variety of the inventions for this single purpose; among which the operose superfluity of mechanism in the dandelion, compared to the thistle, is in itself an answer to this hypo-

thesis; since, in the latter, the same end is attained in a much simpler manner. There are a hundred lichens employed in bringing soil on a rock, where two or three would have sufficed; while this also is one of the answers to the former hypothesis, just as is the case of calcareous spar. The modes of protecting seeds comprise uncountable inventions, and many of them very far indeed from being simple: and in the relative dispositions and numbers of the stamina and pistils, everything beyond the invention for a *Chara* or a *Lemna* may be deemed superfluous. Here too we find peculiar contrivances, as in the *Kalmia*, the *Rue*, the *Barberry*, the *Parnassia*, and the *Cistus helianthemum*, for bringing those parts into contact; an invention for the mere sake of invention, assuredly, when the entire remaining mass of thousands requires no such contrivances: while if we desire an example of a circuitous road to gain an end which is elsewhere for ever attained in the simplest manner, these parts have been widely sundered in the Dioecious plants, for no other apparent purpose than the inventing a very remote remedy for a variation which, but for this, would have been an unwise one, defeating the desired ends. But in truth, I might give the whole history of the vegetable creation in answer to this hypothesis.

If I proceed to some illustrations from the animal world, it is not for the sake of answering that which is far more than answered already, but because of the purposes of this chapter. Why does the ox ruminate, more than the horse? here is an indirect road to a very simple end. The naturalist says that the greyhound possesses a tail to assist it in turning: but the hare and the deer, which outstrip it in activity, do not require this super-

fluous invention. The mouse and the cat neither chase nor turn ; for any discernible purpose, their tails are as superfluous as the overshadowing ornament of the squirrel. The Kangaroo labours under an invention which is an infringement on the general simple and effectual one for quadruped motion : it would have walked better and fed as well under the construction of a sheep ; as it would have run more effectually under that of an antelope. Why should not all of the Opossum tribe have produced their young as these last animals, as all other animals do ? here is a defect made first, as in the Dicoecious plants, with a subsequent invention as the remedy to it. Why was the Bat not a bird, in every thing ; or why a bat at all, interloping with the natural food of the birds, as it does with their place on the earth ? The philosopher makes rules, as if he even defied the Creator to break them. It ought to have the sternum and pectoral muscles of a bird ; it has not the half : the lungs, the feathers ; it has neither. It ought to lay eggs, that it might avoid carrying superfluous weight. The Creator thought otherwise : He has chosen to display His resources, to show that He is unfettered by difficulties, that He does not take the simplest and easiest road to His ends. We inform Him what is necessary to the support of a bird in the air : He has determined that His fishes should fly, as well as His quadrupeds ; as if to show us that His power is unlimited, that He is bound by no rules but those which He makes for Himself. All worms might have been reproduced and continued in the simple manner in which so many are : He has created an army of butterflies, of superfluous variety and splendour, to reproduce an equal army of those worms ; thus taking a circuitous road to an universal

end, and thus departing from the leading laws of His creation on the fundamental point.

The general conclusion is already obvious : while, if we must judge of the Creator's intentions by His works, whenever those are not otherwise known, so we shall not judge wrongfully, however imperfectly, when our inferences do not contradict our authoritative information respecting Him. If He displays His wisdom in Creation, so He does His beneficence : but he also demonstrates His power ; and the variety of His works, with the multiplicity of His resources, are among the evidences of that power. The direct intention to produce variety seems also proved by the system of plans which He has adopted. Obscure as those still are to us, they descend at last to species ; while here commences that final effort of variation, in which no purpose can be conjectured beyond the obvious result ; because, for all uses, it is superfluous. The Calcareous spar among minerals, the Erica in the plants, and the Medusa, Chœtodon, and Echinus among animals, are but examples out of thousands.

Although the argument is completed, the further illustrations are not less necessary ; because they form the demonstrations of the Creator's Power under this view. But, involving all creation as they do, I can admit but little ; as there is much that I can only suggest to those who are willing and able to contemplate nature in this manner.

Any one can range over the quadrupeds in his mind, since they are all familiarly known ; while in them also, the efforts of invention are more restricted than in any other part of the animal world. But the contrast between the Elephant and the Antelope, in form, between

that animal and the Shrew-mouse in size, the peculiarities of the Rhinoceros, the Opossums, the Porcupine, the Ant-bear, the Manis, the Bats, the winged Squirrel, the Cameleopard, and that paradox among animals, the Ornithorynchus, will suggest what any one can extend much further, as this question is concerned; since the superfluity of invention is often as apparent as the variety. Thus we might have judged it unnecessary that a quadruped should have been created to feed on fish: it is a more natural conclusion that this class of animals should feed on the plants of the earth or on each other. A quadruped with the two hinder legs converted into fins, with the tail of a fish, unable to breathe water, yet condemned to live in the sea, is an invention as apparently unnecessary as it is remarkable. Again, if the seaweeds were to be eaten, the fishes or the turtle might have sufficed; yet we find the Dugong, a monster even more anomalous than the seals, curtailed of half its proportions: a fish unable to reside permanently in the sea, and a land animal which cannot reside on the land, where, nevertheless, it must produce its young. Be this a designed gradation or not, it is an effort of invention disdaining all restrictions: but I need not here re-argue the trifling and antiquated hypothesis of a gradation through all created things.

In the birds, the requisites for motion have restricted the forms: the variations have no greater range than is found between the Owl and the Swallow, or the Stork and the Partridge. But we can here note, at least, that difficulty under which so large a number of species has been discriminated; evincing greater power of contrivance than that which is demanded for larger variations: while, once ascertaining them, we know them to be

effectual. And here also, in the Duck tribe, the Parrots, and the Certhias, as in the Humming-birds, we trace that multiplication of species which seems a pure effort of invention without utility ; as we also perceive an evident intention to produce superfluous beauty of colouring, and even a design, we may imagine, to try how far variety and splendour could be carried. The Argus pheasant, the iridescent Pigeon, the Mandarin duck, the Paradise birds, and more, are, like the peacock and the humming-birds, examples of the curiosities of nature ; like the butterflies and the innumerable flowers, the purely ornamental works of the Creator's hand. And if here, as also in the quadruped creation, there are examples of what, were we speaking of human inventions, we should term capriciousness, they are trifling when compared to those in other departments of the animal world ; where forms seem to exist, as if for no other purpose than to show that they were practicable, and where the efforts of colouring sometimes seem as if they had been borrowed from our own devices.

The tribe of the Lizards presents the first very striking examples of peculiarity in invention. The Crocodile is oviparous, without more apparent reason than the Dugong ; it is a quadruped, with less claims and less uses for this perfection of structure than the Seal ; and it has the scales of a fish without any obvious justification ; being, for all essential purposes, a seal, yet with the additional desires and powers of a tiger. He who had seen a Crocodile could not imagine a Chameleon : nor would even the dreams of a painter conceive what the rest of this tribe exhibits, in the Gekko, the Guana, and many more ; where, to purposeless variations, are added purposeless superfluities of structure. In the

Tortoise race, the whole anatomy is distorted; the places of the arms are reversed: it is a mixture of quadruped, frog, and shell-fish. The Frog is an equal anomaly: and the Toad is a greater, since, while almost identical with the former, it is not amphibious; while the double existence of this tribe, being an enormous variation and a most operose contrivance, seems without object. The Serpent races lead to similar remarks. They are worms, with the essential anatomy of a quadruped; or they are terrestrial fishes with lungs: animals of great power and rapidity, swimming on the earth, without extremities, as these do in the water. Presenting a greater difficulty than the birds, there are hundreds of species under this simplest of all forms, discriminated by the most delicate yet effectual distinctions. We might ask why they exist at all, if it is not to add to the variety of creation: they are the food of very few animals, they live on that which others equally consume, and their enjoyments are of the lowest in nature, since those are, to gorge and to sleep; while, esteemed the universal enemy, they are the sole condemned race among all animals: indolent, unsocial, feared, hated, and persecuted.

I formerly gave a general view of the anatomical contrivance in the vertebrate animals, reserving those of the other divisions to this place. The reptiles indeed belong to this division; but there is an important variation which demands notice. A portion only of the blood passes through the lungs at each action of the heart; whence they more easily dispense with respiration, while their heat and their muscular power are proportionally inferior to those in the quadrupeds. As swimming animals therefore, their strength

is on a parallel with that of the fishes ; while, on land, they are slow, or inert, or easily fatigued : yet with exceptions which prove this physiological rule not to be very accurate. Having small brains, they appear less sensible than the quadrupeds ; but possess more of what is termed irritability, from the greater diffusion of their nervous system. I need not, for the present purpose, enter on anatomical details more minute : while in proceeding to the fishes, I may omit all the peculiarities of structure, except the substitution of gills for lungs and water for air.

This is the general, but not the universal proceeding in that race. To have continued the lungs and the respiration of air in a single tribe, is a variation as unexpected as it appears to us purposeless. It is the exhaustion of that anomaly which commences with the seals. We can see that they might have breathed by gills, and that this exception bears no reference to bulk, since the Porpoise is a much smaller animal than the Shark. And the moral variation is not less remarkable ; when the Whale suckles its young with the affection of a quadruped, while the fishes at large are totally ignorant of their progeny. If I formerly described the mouth and the mode of feeding in this fish, it is an invention without a parallel ; as the principle on which it is fed, seems also one of those unreasonable, or unaccountable, exceptions, of which we find so many everywhere. There are not many other essential variations of anatomy among the fishes : yet the cartilaginous flat ones, such as the Rays, and the distorted flat fishes, must be noted as such ; the latter, especially, being a very striking instance, when the simpler principles of the former might have been adopted, and a very circuitous

mode of gaining the same end. If, as has been supposed, the air bladder is omitted among a few of the high swimming fishes, in the *Sepadogaster*, in some of the *Choetodons*, and in more, it is another example of the same kind. The general analogy which is continued from the quadrupeds, is also abandoned by the omission of the podal or ventral fins in a whole tribe; as it is also departed from in the occasional suppression of the pectoral fins. Lastly, under this head, I may notice the viviparous fishes which do not nurse; being another variation in which we discover no purpose but that which is here presumed.

The chief variations among the fishes must be sought in the forms, and in the parts or the appendages, as also in the colours: they are the inventions which strike us in this department of nature: while we cannot but perceive that they are often purposeless, as utility is concerned, and that they are even obstructive to the ends; so that, in some cases, a new counteracting invention is required to remedy the evil. We have seen that in the birds, the variation of forms seems to have been controuled by the necessities for motion; and we might have expected that the same check would have operated in the case of the fishes. But far greater liberties have been taken: so great indeed, that the principle of diminishing hydraulic resistance seems to have been entirely abandoned in some cases. If the *Scombers*, including the *Mackerel*, and a considerable number more, present that form which is, or approximates to, the solid of least resistance to water, there are many more which deviate widely from it, as there are a few which seem to have been constructed on purpose to meet retardation; while taking simple geometrical forms

as a base of reference, those of the fishes range from nearly a sphere down to a prolonged cylinder and to a ribbon, independently of those compressed and wide-spread solids which find no convenient reference in the forms of geometry. A few examples of those can easily be multiplied by any one acquainted with this department.

In the Whale, and still more in the *Spermaceti* (*Physeter*), the form of the head is such as to offer resistance to the water; and so it is, if in a much less degree, in the Gurnards. In the Cod, the shape is far from being calculated for rapidity; it is quite the reverse in the Frog-fish and the hammer-headed Shark; while the *Sternoptyx* is constructed in direct opposition to the mathematical law, insomuch that a mechanic would reverse the places of the head and tail. In the shapes of the entire body, whether we consider mere variety of form, or mathematical principles, we may contrast the Dory, the Bream, and the Opah, with the Gar and the Mackerel, or the Gurnard with the Salmon and the Basse. The Eel and the Turbot, the Sandeel and the Sole, all equally seeking the ground, are the contrasts almost between a worm and a fish. In the *Chætodon orbicularis*, we find the sphere; in the *Ophidium* and *Ophiosurus*, the long cylindrical worm; and in the *Cepola*, *Lepidopus*, and others, the ribbon form; while other *Chætodons*, the *Balistes*, the *Fistularia*, the Lampreys, the Pipe fish, and more, serve to fill up the intermediate shapes: so that more knowledge might possibly enable us to produce a connected series of forms, or a plan regularly wrought out, through all the fishes.

Of peculiarities in invention under form, I may again name the *Fistularia*, in which the head equals one-

third of the body, the *Centriscus*, with its incongruous head and body, and the *Zeus gallus*, displaying one of those strange contrivances which we naturally term capricious. Such also is the frog-fish; being, among the fishes, what the deformed lizards are on the land; and such also is the tribe of the Rays, with their tail and wings, and their strangely contrived mouth: as, among those, the *Aquila* of the Mediterranean is especially remarkable for the extreme display of capricious contrivance. I have already named the hammer-headed shark, and formerly noticed our own two sun-fishes; but they may be added to a list which might be very widely extended.

If, in much of this variation, there is utility for the purpose of distinguishing species, so there is in those diversities of form which we find in the limbs and appendages; though here also we cannot but see that there are purposeless, or even inconvenient inventions, otherwise than as, in this case also, there is always a remedy, or that the animal is perfect, as far as its desires or pursuits are concerned. It was also easier to vary a fin than a wing; since that which only retards motion in the one case might have impeded it in the other. Thus we find the tail forked, reversed, squared, rounded, oval, lanceolate, unequal in the divisions, or very large, or very small, without any reasons, if it be not for distinction, because we see that the velocity does not depend on the size, as is especially remarkable in the mackerel. Thus do the balancing fins vary in form and distribution, probably for the same purposes. If these are extremely remarkable for their length in the *Choetodons*, we perceive a general purpose in the balancing of those round and short bodies: yet

even here we see that superfluity which occurs so often everywhere ; as in the *teira*, where the span of the fins is nearly three times the length of the body, in the *arcuatus*, where they form an elegant crescent, and in the *macrolepidotus*, where they are spun out into extreme slenderness, so as to become a mere ornament. We can see the purpose also of the long pectoral fins in the different flying fishes ; but discover none in those of the Sapphirine gurnard, since, for all the ends of motion, they need not have been larger in this species than its congeners. In the *Holocentrus ruber*, the contrivance in this part is an exception to the general and essential form of every fin ; since the rays are unconnected by membrane, so that it resembles the wing of a bird that should consist of only quill feathers ; performing therefore, under a very operose structure, that duty which a much smaller continuous fin would have done even better. And thus also in the *Engraulis cottia*, we are at a loss to explain the purpose of the long rays which branch from the place of that fin.

The appendages which are not limbs in the rigid sense, give rise to the same remarks. Some of these are evidently organs of touch, or feelers, or enticements to entrap the smaller fishes, under the temptation of a bait : and such is apparently the case with the "beard" in the Cods, the *Silurus acanthotus*, the *Malopterus alia*, and many more, as also with the fishing tentacula of our frog-fish. But though they may serve for similar purposes in other cases, we cannot but perceive purposeless or ornamental superfluity in such instances as that of the *Balistes penicilligerus*, covered with a semblance of branching plants, in the leafy ornaments on the head of the *Scorpaena volitans* and others in this genus, in the

appendages resembling tobacco leaves on the head of *Lophius histrio*, and in the long strings which terminate the tail in the *Stylephorus* and the *Sisor*, and the balancing fins in the *Zeus ciliaris* ; though it is possible that some of these may be feelers, or else enticements. I may say the same respecting those appendages used for defence, which are noticed in the chapter on that subject. The *Syngnathus* can want no armour, when its fate must be, to be swallowed entire. In many more, the weapons, whether for defence or offence, are more varied and more ornamental than was needed for those simple purposes ; as is the case with the serrated horn in the *Balistes geographicus*, and with many other similar instruments ; while the armour of the *Ostracion*, the *Monocentris*, the *Pegasus*, and more, will satisfy any one of the intention, to add variety to utility ; as the *Scoræna* alone would suffice to evince this design, so extravagant is the invention and so singular the combination of form and defences.

In the fishes as in the birds, colour has doubtless been used as a ground of distinction and recognition ; but this cannot have been even a general purpose, far less the leading one, when our own seas possess so few coloured fishes, and where those ends are served without such marked distinctions. The species in the *Labrus*, the *Surmullet*, the red and sapphire *Gurnards*, the *Loach*, and the red *Cod*, comprise the whole of our own coloured ones ; while, like the coloured birds, they abound in the hot climates. In these, the *Holocentrus ruber* is the most splendid, adorned as it is with scarlet and gold, as the *Scoræna miles* is with scarlet alone : but it is chiefly in the *Balistes* and the *Choetodon*, that nature has sported or rioted in the display of colours no

less dazzling by their brilliancy than varied in distribution. In the former quality, they find few rivals, except in the humming-birds and the other iridescent species, and in the very small number of insects thus distinguished; while they leave all the coloured flowers far behind. They may indeed be often said to exceed the birds in colouring; since to the highest brilliancy of local colour united to iridescence, they add a rapidity and extent of change, to which these afford no parallel; as is familiar in the dolphin.

And the inventions in design are often still more remarkable; while there is very little analogous to it even in the birds or the butterflies. The regularity, order, and symmetry, in stripes and figures, are those which the painter of ornaments often adopts, ignorant that nature has anticipated him; as there are many more which he might be long in conceiving, under all his practice. It is as if nature had been borrowing from art, instead of the reverse; and thus are we more struck by the designs of the coloured fishes, than by those in that picture gallery of Creation, the butterflies; just as the pulley muscle of the eye, or the egg layer of the insect, which resembles a sliding telescope, interests us more than the other mechanisms in the animal organizations. Black or coloured bands, symmetrical groups of spots, stripes disposed and coloured in various modes, and much more, are among the principles of these patterns. And since I must refer to figures for these things, I may name the *Balistes aculeatus*, striped with red on green, like a printed cotton, the *Acanthurus vittatus*, similarly striped with blue and yellow, the *Choetodon vagabundus*, in which two sets of narrow red stripes, on a white ground, occupy the fore

and hind part in contrary positions, under the most accurate meeting where the change of direction takes place; the *Lophius histrio*, so singularly spotted with black; the beautifully striped *Sciaena cirrhosa* and *Chætodon imperator*; the *Chætodon bicolor*, so equally divided into white and crimson; the *Chætodon faber*, with its dark blue and white bands; the *teira*, with black and yellow ones; and the still more remarkable incurvated white ones of the *arcuatus* on a black and brown ground. Yet these are but a few of hundreds, uniting to their endless patterns every distinct colour, and almost every broken tint, which painting can command.

Why all this profusion of variety and beauty has been lavished on this race, it is difficult to conjecture; since it is superfluous for the sake of distinction or recognition, and must generally be an impediment to concealment, instead of aiding it. It can scarcely have been for our sakes; from the rarity and difficulty of access to them, and from the evanescence of most of this colouring when removed from the water. Be it but for ornament, as it must be, serving no other purpose, why is it not intended as a source of pleasure to themselves? This would be much more easy to ridicule than to answer: as he will find, who shall examine the source of his objections. No animal must possess any sense of beauty, because that is among the intellectual distinctions of man; just as it must not possess reason; it is an animal, a beast: the sound of the words is half the source of this judgment, while vanity, habit, and ignorance, form the remainder. The Creator appears to judge very differently on one of those subjects, and not improbably on both. The unfortunate fish especially, whose only relation with man

is to be destroyed, and treated as if it had no feeling; seems excluded from all regard; yet that is not an animal without moral feelings, which learns to recognise its master and to lick his hand. If the doctrines of physiology are of any value, the Dolphin, possessed of a brain rivalling that of man in its proportions, should be highly endowed with mental faculties of some kind. But who that knows the birds can doubt that they are aware of the beauties of their own plumage, and that their partners at least know how to admire it? The self-admiration of the Pigeon is familiar; a mirror secures it from deserting its home. The Turkey, the Woodcock, the Peacock, and many more, display their trains to please their partners; while their pride is as evident as it is proverbial: the latter animal giving the strongest proofs of it, by shunning all society, and concealing itself, as if in shame, should design or accident have deprived it of its splendours. If I mistake not, the same consciousness of beauty exists in the butterflies; as I have no doubt that it pervades all creation, and is one of the beneficent gifts of the Creator to all His creatures.

In proceeding to the marine crustaceous animals, I may, for the present limited purpose, follow the ancient order of natural history, and thus sketch the anatomy of these, of the terrestrial ones, and of the insects, under one view, so as at least to convey a general idea of this great variation. In all, the muscles are within, and there is no other bone than the shell or skin. In neither is there any brain within the head, or any spine; the substitute, or the basis of the nervous system, consists in two knotted cords, or nerves with ganglia; of which the uppermost, surrounding the œsophagus, is

considered to represent the brain in the vertebrate animals: and thence it is, that the loss of the head in the insects does not deprive them of life. The marine crustacea breathe by gills, like the fishes, and have a double circulation, without a properly distinct heart; but the blood is white, and the animal is cold. In the terrestrial crustaceous animals, or Arachnideæ, and in the insects, there is a large blood-vessel serving the purpose of a heart; but its ramifications do not seem to have been traced, so that the process of circulation is not known. But in both these, breathing air, the respiratory system consists in numerous tracheæ, communicating with distinct lungs in some cases, and in others, believed to ramify all over the body. In all, the intestinal system is simple, and sufficiently similar not to require any description here.

In all of these animals, the jaws are reversed in position and action, compared to those of the vertebrate division. In the marine ones, there are at least six, sometimes furnished with palpi; in all the terrestrial, the mouths vary so much as to admit of no general description; though the leading distinctions are provisions for biting and for sucking. In the marine crustacea, there are never less than ten legs; while two, or more, or all of these, are sometimes hands; as, sometimes also, two or more are fins: while in some, there are fins in addition to the legs. In the arachnideæ, the legs are generally eight: in the insects, six: though in a small and ill-arranged division, to which the Centipede belongs, they often far exceed a hundred. The marine division possesses antennæ, generally amounting to four: a new limb, to which there is no analogy in any of the preceding races: the arachnideæ have palpi, but

no antennæ : in the insects, antennæ and palpi are universal, but under infinite varieties. The marine animals change their shells once a year, forming a new one within the old, by a secretion of calcareous matter in the skin ; and they grow in the interval, but very slowly ; as their lives are prolonged to many years, often to twenty, thirty, or more. They can also throw off their legs and hands, reproducing new ones. They have but one pair of eyes, which are generally moveable. Their terrestrial analogies are also produced from the egg as they are to remain, growing by changing their skins ; sometimes it is thought, without this. In these, the eyes range from two to eight. All the marines are oviparous ; there are a few exceptions among the terrestrial. I need only further note, to prevent error, that I have not here distinguished the marine Arachnideæ, ranking them as crabs, which, for all the present purposes, they are.

In the insects there are some peculiarities still to be noticed. They are, through a very large division, separated into three parts, the head, thorax, and body ; but natural history, under its most recent arrangements, is still but a mass of confusion on this subject ; a mixture of scientific efforts and popular usages. Their eyes are not yet intelligible. There are three or more simple ones on the front of the head ; but besides these, there are the conspicuous compound ones, consisting of hundreds or thousands. They hear and smell ; but the organs of those senses are unknown. They have sometimes wings, being two or four, occasionally protected by hard shells : and these wings are sometimes temporary. All are oviparous : but there are, in some, animals which are practically neutral. All the winged

ones, and some others, appear to lay double eggs, as I have explained in this chapter and in the eighteenth; the first hatched animal being a worm, and the second, which is a germ growing within that, being the representative of the parent, and being hatched during the repose of the worm, which dies when it is completed. The greater number never grow: a few grow like the crustacea, by changing their skins.

In the crustaceous marine animals, the variety of invention exceeds all that we have yet seen; including almost everything that can be imagined of caprice and deformity, as there was here no check, under the necessities for motion, and as the materials and the element admitted of any liberties, and of sizes also infinitely surpassing in minuteness those of the smallest fishes. The range is from that of the great king-crab down to a microscopic one: while, in the whole of this race, the general moral principle is also remarkable, consisting in great strength to attack and resist, united to a corresponding activity and ferocity of character. I do not here separate the Monoculi; nor need I, for a purpose like this, distinguish the Amphipoda or other divisions of naturalists.

In this extensive division, the variations, as in the fishes, are in the forms of the body, in the forms and numbers of the limbs, and in those appendages, which, if they are sometimes defences, seem at others to be mere superfluities or ornaments, whether for distinction or not. There is little attempt at colouring, the tints being generally neutral, for concealment: a few only display grotesque paintings, or coloured patterns; among which a black and white chequer on the tail of one of the minute and yet undescribed Monoculi is of

the most remarkable. The lobster, or shrimp, the common crab, the king-crab, the spider-crab, and the long-legged Phalangium, belonging to the Arachnideæ of modern naturalists, must serve for familiar types of the most prevailing inventions in form: but there are no well-known ones to serve this purpose as to many more. The greatest diversities of invention will however be found under the tailed ones, for which the shrimp is a type; while it is here also that the chief caprices and deformities occur: the latter being often such, that were they living and land animals, we should be afraid to approach them. The Parthenope, in particular, seems to have been made for the purpose of inspiring horror: it is like the Scorpæna among the fishes, or the Gekko in the lizards.

But it is almost fruitless to name the various shapes of the bodies, in round, oval, prolonged, squared, heart-shaped; while in some, as if to exhaust invention, it is irregular, or unsymmetrical; being the only instance where that occurs, I believe, if I except the Mollusca, where it is the leading principle of construction. In the numbers and proportions of the legs to the body, in finned legs and feet, in the shapes of the hands and pincers, in antennæ, palpi, jaws, tails, fins, and more, the variations and inventions are without end; while if spines are defences, there are bristles, as in a Grapsus, and, in a great many, tubercles, projections, and irregularities, in which we discover no object; the result being that various and unexpected hideousness of aspect which so abounds in this race. If I formerly pointed out some beautiful mechanisms in this tribe, they belong to the head of invention; though a long chapter would be required to describe the exist-

ing ones. Seeing a purpose, we have but to admire the ingenuity, as in the flattening of all the feet of the *Matula*, so as to render it perfect for swimming and for walking both, without any addition of fins: comparing the long pincers of the portimus forceps with the hand of a crab, we presume on an especial purpose, though we do not chance to know what that is. But when we find a shrimp whose antennæ are jointed legs, used for walking, we can see no object in such a variation, but that of displaying invention, since it breaks through the universal rule: it is a case resembling that of the tail of the kangaroo. In the *Cyclops*, on the extremities of whose immense antennæ there are two branches, at right angles, revolving in a half circle round them, we must be content with admiring the invention; since here also we can conjecture no purpose. That these two latter animals have been hitherto unknown to naturalists, needs not prevent me from mentioning what is known to myself.

But if here, as for ever, I must refer to drawings and cabinets, so can I only note the next, if connected novelty of invention, which occurs in the *Isopodes*, of which our wood-louse and the common marine *Oniscus* may serve for a type. For the same reasons must I pass the *Arachnideæ*, whether terrestrial or aquatic, though the diversity of invention is very great, as they are sometimes also distinguished by splendid colouring; merely suggesting that they include many crabs, with all the spiders, the scorpion, and the mite; while the invisible *Acari* will suggest the range of magnitude.

If it is for the reader to study those objects, and to repeat the same reflections on them, still more must he do this in the case of the insects; that overwhelming multitude

which it is for ever necessary to reject, from its unmanageable multiplicity; while the most easily trusted to readers, under the number of books and collections which are so easily consulted. Though there should be no more than the two hundred thousand species supposed to be known, this alone implies an enormous mass of inventions; since in every one, there is some circumstance by which it is distinguished from all the rest. It is a power of variation which is quite inconceivable, except of Omnipotence; while as I formerly noticed of the *Erica* and *Medusa*, the mere number implies that delicacy in variation, of which indeed we have abundant proof in the general resemblance that pervades divisions and families, and in the distinctions themselves, when once we attain to know them; such, for example, as the distribution of the tendons of the wings in the flies which otherwise resemble each other.

But there is here much more than this, and of a more decided character. The invention of the double egg, to which I have just alluded, and the purpose and nature of which I have explained elsewhere (c. 18), is as striking a contrivance as it is an exclusive one, confined to this department in creation. The fly, laying the ostensible egg of a worm, becomes also the ultimately viviparous parent of a progeny like itself, through this circuitous road; while that worm, a neutral animal, without progeny of its own, is the viviparous deputy, performing the maternal office for its twin, the true representative of the parent, and the parent, in its turn, of future worms and future representatives. How naturalists have contrived to overlook this plain fact, important as it is in the history of the animal races, they must themselves explain: anatomists at least

should not persist to this day in speaking of the transformation of larvæ into flies, when they should see that the change of the structure and organs of the former into those of the latter is impossible, and ought to know that it is not the fact. And though Greek fable may still be allowed its rights over the apparent mystery of the butterfly, a rational theology cannot any longer be permitted to use it as an illustration of that great change which we have been taught to expect through the religion of the Gospel.

I have elsewhere almost passed over the variety of inventions in mechanisms in this tribe, as I must do here ; though amid the endless number, under limited sets of uses, we cannot but believe that the intention has been, here, as in all else, to display resource. In the colouring, and especially in the case of the butterflies, we can no more doubt it than in that of the birds and the fishes ; while a contemplation of the forms must very often lead to the same conclusion. In these, I need not even detail the leading types : there is scarcely any one to whom they are not familiar, or at least accessible ; and the eye of him who chooses to look at creation in this light, will suggest thoughts which will never follow from words.

If, in the molluscous animals, the varieties of invention continue to accumulate, we here also find a fundamental anatomical one, differing from all the preceding : while for the general reader, it must suffice to say that this division includes the cuttle-fish and the shell fishes, with many other marine animals for which there are no popular types ; and, on land, the tribe of snails. Like the preceding division, these have no skeleton, though sometimes containing a single internal bone. The ner-

vous system does not so materially differ from that of the former as to require description here, but seems even more independently diffused. The blood is white, and the animal cold ; but there is a double circulation, under some variations, as in the vertebrate tribes ; while the heart is replaced by a main artery, just as in the insects, but under modifications sometimes producing the semblance of more than one heart. The aquatic ones have gills, sometimes lungs : and the terrestrial have lungs of course. Some are viviparous ; and they are not all divided by sex. One race alone possesses eyes and assignable organs for hearing ; but none seems without this latter sense, as, without visible organs, it is very lively in the shell fishes. It is probable that the nerves of hearing are diffused over the surface, as those for light are in the Medusa and other eyeless marine animals.

In all the preceding races, the anatomy is symmetrical, or the external parts are double. But it is not so in this division ; while there is a similar irregularity in the interior organs. The muscles are attached in various ways to the soft parts, while the motions are changes therefore in the figure of the body, and are for the most part slow. The naked ones have a mere skin, or a skin including some calcareous matter ; while an increase of this deposit produces the shell in the shell fishes ; the epidermis often remaining on the surface. The bivalves are closed by a powerful and active muscle, and opened by the elasticity of the hinge ligament.

Neglecting the divisions of natural history, as being here equally purposeless and inconvenient, the range of magnitude is the first thing which strikes us in the shell fishes ; extending from the great Chama down to the

Miliolite not exceeding a pin's head in size. Omitting the multivalves, as a very limited division, there are but two leading inventions, the bivalve and the univalve forms; while, in this tribe, it is the dwelling, or the skin, not the animal itself, which is the ostensible, and often the only subject of variation. Yet under these two fundamental arrangements, the mere varieties of form surprise us by the resource which they display; as they ought to do by that elegance and diversity of geometric lines or solids, which, if we cannot reduce them to algebraic equations, seem as if they often followed some mathematical laws. But every one knows what these are; as all are acquainted with that careful and various painting which they exhibit; in this case, at least, purposeless to all but us, since it is not often to be seen in perfection, without removing the epidermis. And as I formerly said, we can come to no conclusion here, but that which I originally suggested; since all the beauty and variety, whether in form or colour, are utterly purposeless: it is the first case in which we are quite sure that the diversities cannot serve, even for mutual recognition; in whatever other manner the ends intended by this are accomplished.

If I pass over the multivalves, including the familiar Barnacle, I must still note them as presenting another set of inventions; while conforming to the popular division by shells, I must however point out a great variety of invention in the Annelides, or shelled worms, under the genera *Serpula*, *Amphitrite*, *Dentalia*, *Siliquaria*, *Terebella* and more; though there are also some soft or shell-less animals in this division, such as the earth-worm; all of them anatomically differing from the preceding, and more resembling the insects, while con-

taining red blood. If I here also name the chambered shells, such as the Nautilus, it is to suggest another great diversity of invention, under many varieties, as I formerly pointed out the peculiarity of these floatable shells: while, under the usual view of utility, these are remarkable superfluities of invention for the sake of an animal which resides on the outside of its ship. Here also, as if to increase variety still further, we find an extension of the contrivance for the cetaceous fishes, in the Planorbis, Lymnea, Auricula, Physa, and others; breathing by lungs, and compelled to navigate their shells to the surface to seek air. From operose and circuitous contrivances like this for gaining a general end, I know not what can be inferred but the intention to display power: while assuredly at least it will not be said, that in giving lungs to a shell fish, and enabling, as compelling it, to float to the surface a shell which it cannot be said to inhabit, the Creator has taken the shortest road for attaining His ends.

The naked Mollusca presents another of those tribes abounding in novelty and variety of invention, often such as to present the most incredible forms. Few however beyond the cuttle-fish are popularly known; though this, in all its species, is certainly one of the most singular of all the contrivances for an animal form; as its superfluity of external mechanism must particularly strike us, when we see that the simplest fish gains all its ends, and the same ends, on far easier terms. It is a parallel case to that of the nearly two-hundred-legged centipede, unable to travel so rapidly as the serpent which has none. Further on, in the same division, we find contrivances utterly distinct from this; animals without feet, sometimes with tentacula, sometimes with shells

covering their tails only, swimming rather with wings than fins, as if they flew through the water, or, like the *Onchidium*, obliged to seek the surface to breathe air, and again, like the *Ascidia*, condemned to a roosted and vegetable life. But I must refer to plates, as I have done to collections, those who do not chance to be naturalists; naming *Clio*, *Doris*, *Polycera*, *Tritonia*, *Thetys*, *Glaucus*, *Scyllæa*, *Eolidia*, *Tergipes*, *Pleurobranchus*, *Aplysia*, *Phyllidia*, *Acera*, *Notarchus*, and *Bulla*, as genera of reference for these extraordinary diversities in invention.

But if that is far indeed from being exhausted, there is also a new principle of anatomical construction yet before us, in that division which natural history terms radiated: a very loose division it must be confessed, where the very fundamental principles so often differ; as it assuredly is not founded on the Creator's own plan. The nervous system has not yet been found, nor has the circulating one: it is a rash conclusion that neither exists; while I have examined this question in a future chapter (c. 29). Gills have been found in many; which seems a proof of even a complex circulation. It is said that there are no organs of sense; but all hear, and all see light at least, while eyes have been observed in some. Those in which no gills are seen, require aerated water, and often consume a great deal, as the *Medusæ* do; which proves more than these anatomical hypotheses admit. Many, even of the most microscopically minute, have a very compound intestinal system: some, like the *Hydra*, have either no stomach or are all stomach, as we please to view them. But it is in vain to pursue such unmeaning anatomy as this, and under a term which is worse than unmeaning: when science shall be cured

of the fault of deciding according to its own want of knowledge, the animals confounded under this division will be arranged in another manner. I need only add, that there are, here, both viviparous and oviparous animals, with colonial animals forming plants, and that a few, especially requiring to be distinguished from all the rest, reproduce by means of buds and offsets. But the confusion of natural history is at least the variety of the Creator.

Fortunately, the leading forms or types of these are better known to the general reader than the preceding ; so that these remarks will be more intelligible. The general contrivance for the Echini is very peculiar ; and I formerly pointed out that extravagant superfluity of mechanism for no utility, which illustrates the present argument so strongly. The animal itself is in the lowest scale of existence ; without organs of sense, and apparently without any of the finer senses ; evidently not hearing, and being quite precluded from seeing, even light ; while being little more than mouth and stomach, gills and ovaries : the beautiful shell itself being almost vacant, a mere basis for a thousand nearly useless legs, when it is slower than a snail, or, as defences, defending nothing, when there is nothing within to be eaten, after the eggs are laid. Here also I must notice the extraordinary multiplicity of forms under the several present divisions of this genus ; being one of the most remarkable cases of all those in which there seems to have been an attempt to exhaust invention ; while we cannot but be struck by the selection of such an animal for such a purpose ; since if there is any one in creation where one form might have served, whether for the uses of the wretched being itself, or that of its enemies, it is this.

The Star fish, as a single invention, with its endless species as subsidiary ones, leads to similar remarks, excepting that the difficulty and complication of the mechanisms far surpass that of the former. The animal is almost a vegetable in sensation, as it is a snail in motion ; with more apparatus and nicety of mechanism, and multiplicity of parts and fittings, than a hundred quadrupeds, and with legs enough to move more than a hundred of those. If we look at the *Caput Medusæ*, it is but to increase this wonder : and thus it is with the *Enerinus* ; the workmanship of which, compared to its uses, would be fully estimated, under the present view, by the artist who should attempt an imitation in ivory. But the great labour to little purpose is not thrown away by Him who designed to show us what His power and His resources were ; and who has, in this also shown us, that He has set no bounds to the means for attaining the ends which He had in view, that He is checked by no considerations of economy, and controlled by no difficulties.

The contrast between this invention and that of a *Medusa* is diametrical, while the simplest animal is also the most effective of the two, though often without a limb or any substitute for one. The desires, the pursuits, and the offices, being as nearly identical as possible, we can easily imagine the minds identical, or suppose the two to change places, leaving the *Asterias* as happy, and more able than it is now. And since the mind, with its enjoyments, is the end of the Creator in producing any animal, we are the more forcibly struck by the contrast, and in the former case, with the extraordinary superfluity of invention for the sake of one of those minds : since, looking at His works under this

narrow view only, it is pure waste, and not less in defiance of simplicity and utility, than of economy.

Here also, as in the *Echini*, we find that exertion of contrivance, as I formerly noticed, through which species so numerous have been founded on a basis so simple ; a mere cup of cellular membrane filled with water, in the manner of the vitreous humour of the eye, containing or supporting the stomach and the ovaries, but no other organ that can be discovered, nor even a pretence to limb or appendage : while the cup itself forms the swimming machinery. And this is effected, partly by varying the shape of the body, and partly by the addition of tentacula of different kinds ; thus giving rise to hundreds of species, to which I have added twenty, in a few days, without the least surprise, as I doubt not there are many more remaining to be discovered. We may view the *Beroes* as refinements on this invention ; while here also, as I formerly remarked, the additional mechanism is purposeless, because the *Medusa* is often the more active animal of the two, while, in the essential construction and the pursuits, there is no difference. In this genus, the intention to produce variety seems also peculiarly evident, because the plan of variation is more easily traced. The body, commencing in a sphere, proceeds through a succession of ellipsoids, till it becomes a triangular pyramid : the fins extend, first, the whole length of the body, in rows of eight, six, four, and two ; occupying next, the anterior half only, and lastly, the posterior half ; while in addition to this, their own shapes vary from round to triangular, and to acutely narrow, resembling bristles. Such at least are the limits of my own knowledge in this family : I doubt not, that in every other one, a systematic intention

could equally be traced, were we in-possession of the species: while if I have thus selected this single instance, it is that I may turn the attention of others to this mode of examining nature, everywhere else. And since I may unite these with the Medusæ, as animals under but one form of mind, and therefore essentially identical, we may contemplate the whole as a single animal, in many different dresses; while these constitute the inventions. Of all these imperfect animals, as of the shell fishes, I need scarcely add, that the distinctions of species can serve no purpose of recognition to themselves, for want of senses, and that they are no distinctions as to the fishes, which prey on all indifferently; so that we must forcibly conclude the Creator's intention to have been directed to ourselves.

It being purposeless to proceed in this manner where the animals are unknown, and can be referred to no familiar types, I must now be content with naming a few genera, without any regard to order, as names for reference to those who may find them in nature or seek them in the plates of natural history. Such are, among others, the families, often also highly varied in the species, of *Holothuria*, *Molpadia*, *Sipuncul*, *Priapul*, *Porpita*, *Velella*, and *Physalia*; of all of which, as of many more, I might say that they would be incredible before experience, while they often seem as if they were mere experiments, to try how far the forms of animal life could be modified. It is, evidently, only among aquatic animals that such strange contrivances were admissible; and hence is it that the marine creation affords a diversity and extravagance of invention, which we discover nowhere else, not even among the insects.

The nature of the *Hydra*, or polypus, is known to

every one ; and it offers an entire novelty in invention, under its reproduction by offsets and by cuttings : in this divisibility resembling vegetable life. The metaphysics which allow no perception to plants, easily overlook that fact in them ; heeding nothing of the divisibility of that which their hypotheses consider to be without extension, and therefore indivisible : they do not appear to have reflected on the divisibility and multiplication of consciousness in the present case, while that cannot be refused to the thing which desires and wills, attains and is satisfied. But this animal is a remarkable invention also, even in a physical view : the exhaustion of contrivance, if we begin from the complicated animals ; the commencement, if we take them in the reverse order. It is a stomach, with the least possible superfluity of limbs for feeding itself : while that seems also equivalent in power on each surface, since the hydra can be inverted without injury. It is a further variation on this invention, to have fixed the animal to the soil ; since between the *Actinia* and the *Hydra*, the essential differences are not important under this view. But they whom the ancient speculations of natural history have misled to consider the fact of rooting as constituting the link between animal and vegetable existence, must recollect that the rooted *Ascidia*, already noticed, is as complicated and perfect an animal as a snail or an oyster.

This will appear again, in considering the great coral race, deserving a far wider examination, under invention, than I can here bestow on it, when the species, often rivalling plants in variety and beauty, amount to a thousand and more, ranging from the *Sertularia* and the *Sponge* up to those elegant structures which every mu-

seum displays, and under a diversity of substance which varies from membrane to horn, to fibres emulating spun glass, and to shell, sometimes resembling ivory, and, at others, stone. The anatomy, as well as the varieties of the animals themselves, are still however very little known. They are not, any more than the *Vorticellæ*, the simple *Hydræ* once supposed; while there seem to be different anatomical structures among them, not less complex than those of the former animal, to which they often bear so strong a general resemblance; though perhaps the circumstance of their having tentacula on a cup, while the *Vorticella* has ciliæ, connects them more nearly with the *Zoanthus*. The remainder of the anatomical contrivance I have described elsewhere (c. 20): in showing, that in each plant, or colony, there is an animal bond uniting the whole into the general form, as, in the hard ones, a secretion of shell renders this the stony plant so familiar. And if I refer to that chapter for what I need not here repeat, so must I equally refer the reader to collections, that he may here also compare the variety of invention with the evident inutility; since the reasoning is the same in this case as in the preceding ones.

Though this chapter is limited to varieties in form, the reader ought not to pass over the metaphysical fact, in this and the other cases of the colonial animals, since it is among the most striking of the Creator's inventions, as it also possesses its varieties, while we do not always see the utility. In the gregarious animals, it is a simple association, or a submission to the command of One, for purposes which I have elsewhere explained (c. 53). In the bees, it is both, for the execution of peculiar, useful works, and for the care of a general offspring.

In the colonial coral animals, we see no end, if I except the construction of rocks by a few ; while the association is compulsory, under a mechanical force, for the production of a work in which we discover no purpose. If there were a will to separate, there is no power ; while in the united *Vorticellæ*, there is even less of the appearance of utility, since no work is produced ; while there is also an occasional permission to separate, with a will so to do, though we are not yet certain, that in all cases, the object in this proceeding is the production of a new detached colony. The *Salpæ*, which seem able to free themselves whenever they please, unite into the shape of a single animal, and swim as if they were all under one volition, for no end that can be imagined : while though the *Pyrosoma*, like the *Botryllus*, is united as a republic, within a cylinder, there is nothing to prevent the individual from rebelling, but that instinct of a common volition to act together, in which we are equally at a loss to discover any object.

The minute and microscopic aquatic animals form such a mass of confusion, under the term *Infusoria*, that it is in vain to attempt any arrangement of them at present. They are the disgrace, if I cannot say the special one, of naturalists, who, bestowing their whole lives on subjects of this nature, might at least do that, in this and far more, which requires no powers of mind, no reasoning, demanding only patience, industry, and eyes ; and whose patience at least, however misapplied, will not be disputed, when it could be exerted for half a life-time on the anatomy of a single caterpillar, with a result, in fame, withheld from those who have been the enlighteners and benefactors of mankind. I have noticed a few of these forms, in a subsequent chapter on

the animal motions ; but there are hundreds for every one there described, while any attempt at enumeration would be fruitless, without figures of reference. They are however not less varied in invention than any of the marine ones which have preceded, under a very diverse essential anatomy, and under an endless variety of external forms. And they are far indeed from being the simple contrivances which they were once supposed ; often indicating, on the contrary, structures as complicated as those of the larger animals. It is said that eyes have been seen among some of the most minute : I have not had that good fortune, but cannot doubt their existence, when hundreds of different kinds can be collected in one small vessel of water, moving with the utmost rapidity in all directions, under a dense crowd, yet never coming into contact.

But although I must thus pass over this vast additional set of contrivances, and am not able even to refer to figures, where so few have been figured, I will point out a single instance to prove that the intention to produce variety is as conspicuous here as among the larger and the more complicated animals. Nothing can be imagined more simple in form than an animal without limbs, resembling the section of a hair ; a straight simple cylinder, and also of microscopic dimensions : while it might not be very easy to suggest the means of producing many species under such a genus. Yet in this new and nameless animal, there are twelve species, perfectly distinguished by means of coloured rings, differently proportioned, and differently distributed ; as there is one also in which the distinction consists in a chain of minute circles extending the whole length of the body. How much further this plan has been

wrought out, remains to be known, since this animal is not described by naturalists ; but it is plainly a principle of variation which might be extended much more widely, as I do not doubt that it has been.'

If I have, in this sketch, passed over thousands of forms for every one that I have noticed, so have I omitted entire classes, and one especially, among the worms, in which, however, naturalists well know the peculiar, as well as the generally disagreeable or disgusting varieties of shape. It is the naturalist indeed who will be the only competent judge of the subject of this chapter, since he can seek it in his own knowledge : but it will be something if I have succeeded in better illustrating the view with which I commenced it, and in conveying to the general reader some notion, however slight, of the inventive power and the resources of Omnipotence.

CHAPTER XXVI.

ON THE VARIETY IN PLANTS AND MINERALS.
CLEANLINESS OF CREATION.

IN continuing the preceding sketch through the vegetable world, I need not pursue either the argument or the illustrations in the same manner, since the general purpose is already answered. Nothing remains to add to the former sketch of the anatomy ; the diversities of form, great as they may be, are few compared to those in animals, as the number of species is very far inferior ; while if the greater number of the forms is very generally known, any botanist can recall to his memory that which is not universally familiar. It will suffice to offer a few popular remarks, for the purpose of directing the attention to the present mode of contemplating nature ; to reflections on the Creator's design to produce variety without regard to other ends, and to an examination of those resources in invention which display His power.

The first thing which must strike us, in the plants, under the present view, is a system of invention or variation to which there is no parallel in the case of the animal world ; while the consequence is the production of variety and beauty superadded to all that which results from the forms and numbers of species. The dis-

tinctive characters of animals, or the inventions for families and individuals, are the only inventions and variations which they present, as their total forms are also constituted by those. But independently of the analogous characters by which plants are distinguished and individualized, there is a further mass of inventions, in those general configurations, which are, for the most part, independent of these characters, and which, if they do not distinguish every species by a new form, produce a very great number of highly distinct ones; while it is those also which, on a general view, conduce most to the variety and beauty of creation.

It is not the specific characters, but the general forms, which render the feathered Ferns the ornament of our hedges, and the Petasites that of our river banks; the Reed owes its beauty to that grace and flexibility which are independent of its essential distinctions: the pruned and stunted Vine of the vineyard retains all its characters, but its beauty is gone; and whatever the Hop may owe to the shape of its leaves and its volubility, those alone would not confer that picturesqueness of beauty and grace which flows from its wild luxuriance and entanglement. This is even more striking in the trees, where the distinctive characters seldom conduce to the general one, as they are also often undistinguishable, except by a botanist: while the Oak, the Beech, the Ash, the Poplars, the Cedar, the Firs, and the Willows among ourselves, afford illustrations which any one can extend far more widely.

But there is still another mode of invention or variation in this department, constituting, with the former, an almost endless source of variety and beauty, to which there is not the slightest parallel in the animal world,

if we except a few rare cases, under man's cultivation, and a few further changes of colour for special purposes. In this division of nature, all the forms, whether characteristic or not, are definite and invariable ; while in the plant, though under the preservation, generally, if not always, of a physiognomy which the botanist learns to recognise, it is scarcely possible to find two individuals of one species which are alike, unless it be among the very simple ones ; such as the grasses, the unbranched mosses, the ferns, and a few more : while even in those, a difference of luxuriance, or size, often confers very strong distinctions of general character on examples of the same plant. The coronet of plumage which constitutes the common Polypody in the shade of a moist wood, is a very different plant from the separated leaves of the same species in a dry hedge ; as is the luxuriant Poa or Aira of a rich meadow, from those which have had no soil but a bank of sunburnt gravel or a brick wall. But in general, the diversity of the total form is unbounded ; while most striking among the larger shrubby plants, and the trees, since the range of practicable variation increases very generally with the dimensions. And adding to this the differences of size in the same species, the result is a system of variation or invention, superadded to all else, which widely extends the variety and beauty of the vegetable world. As this operates on the general face of nature, it is most sensible to the painter's eye ; as it is that eye also which best distinguishes this class of variety ; to which indeed is owing much of the beauty of landscape, and a very great portion of the total beauty of the vegetable world, perceptible even to those who do not look at nature with the same cultivated feelings, and who do not ana-

lyze the causes. We shall immediately indeed be sensible of this, in recollecting that among our own few thousand species, there are not many hundreds which are seen by those who are not botanists, and that if every individual of a species resembled every other, as animal species do, the result would be a tiresome uniformity. He who will imagine this of every Oak, for example, will immediately perceive the effect: while at present, that tree, and most others, are now endless sources of variety and beauty, both in their own details and in their influence on the landscapes of nature.

If the resources in invention are here boundless, so is the inutility apparent: there is no purpose but beauty; the motive is beneficence, if it is not also the display of power. Nor can the intention to produce this beauty be doubted; though the usual thoughtlessness attributes all these inventions to chance. The organization of a plant is as definite as that of an animal; the seed never varies; the germ is for ever the same. The just conclusion should be, that of a constancy in the final form, under the usual hypothesis of regularity and "laws," as it is in the animal. But in these, constancy was necessary: in the plant, it was possible to produce variety, without interfering with utility; and the Creator has acted accordingly. If there is not design in this, I know not why it should be sought anywhere in the variety and beauty of the vegetable world.

My limits will not allow me to pursue the inventions which relate to families and species, even in the slight manner which I have done in the animal world. Nor is it necessary; since the far greater familiarity of these objects, with the extensive access to them, renders al-

most every one competent to this, as far as the present purpose is concerned. I had also occasion, in former chapters, to point out many of these inventions, both as they relate to distinction, and to utility; as I have further been compelled to do in some subsequent ones: so that while the reader can turn to those, it will here suffice to select a few cases analogous to those which I chose in the animal world, as further illustrations from this department of creation.

The leaves of plants, being constant and definite forms distinguishing species, offer a more convenient illustration of a regular intention to produce variety, than the flowers do; on account of the unity of the essential object, and the consequently greater simplicity in the system of variation; while they afford sufficient proofs of inventive power. But it must suffice that I trace a very meagre skeleton of that which any botanist can fill up from his recollections.

Taking a mere cylinder, a hair, as the simplest of forms, we find it modified in endless ways. It is very long, or very short, or very slender, or the reverse; or it is rounded at the extremity, or pointed, under different degrees of acuteness; while again it departs from the pure form, by becoming compressed, or ellipsoidal, or spindle-shaped in the section, or semicylindrical: as still further, the cylinder is furrowed on one side, or ultimately, so deeply furrowed as to resemble a flat leaf longitudinally doubled. Any botanist can recollect examples in *Festuca*, *Spergula*, *Arenaria*, *Plantago*, *Juncus*, and more than I need here name. Again, we find it hollow, as a pure cylinder, or a portion of a cone, or of a double cone, in *Allium*, intersected by joints in *Juncus bufonius*, and otherwise modified in *Sedum*,

Mesembryanthemum, and more. Thus also do we find it under modifications in the fir tribe, the Erica, the Casuarina, and many others : while in the Cypress, a sort of external articulation is added to the general outline.

It is an easy transition hence to the flat or ribbon-shaped leaves, where also we find a set of variations greater than could have been anticipated ; and often so delicate, that though we may recognise the leaf of a species of grass, it cannot be described in words. It is the same in the leaves of the flags and certain of the liliaceous plants ; where, though such diversities as occur in the shape of the point, the existence of a central keel, of striæ, in a want of parallelism of the outline, or the reverse, or in those thickenings of the middle part which give triangular or rhomboidal sections, may sometimes be described, we must more commonly be content with recognising the individual leaf when we see it, while the certainty of that recognition proves the intended nature of the variation. Narcissus, Iris, Agapanthus, Butomus, offer illustrations which I need not extend in this department, as Poa, Festuca, and Carex may here suffice for the other.

But hence, through the lanceolate to the oval, lies the great range of form in the simple leaves ; while numerous as these now become, under much greater power of variation, the constancy is not less remarkable than the variety. Here also we most easily imagine a definite plan wrought out from the varieties of the ellipse ; although in no instance does the mathematical figure occur : but it would require a far wider comparison of species than is easily attainable, or perhaps possible, to make out this plan, if there be such a one. It is on

this fundamental set of forms also, that the chief system of variation takes place ; by serratures of different shapes, sizes, and complexity, by scollopings regular or otherwise, by undulations, by single indentations, producing the direct and reversed heart-shaped, by the addition of a point, or more, or by lobes rather than points, ultimately passing into the lobated leaves which lose all resemblance to the original basis of departure. Hence also the forms termed hastate and sagittate, with the leaves of a nearly circular outline, and far more than it is possible to name here ; while by a peculiar insertion of the footstem, as in *Tropæolum*, and *Coltyledon umbilicus*, other distinctions again are produced. To give examples of these forms, however, would be to enumerate a catalogue of names to no useful purpose, as they are easily supplied by any one. And though I named the ellipse, it must not be imagined that this mathematical curve has regulated these forms ; according to an idle hypothesis which I have examined in a future chapter, where it seems to have been forgotten, that the several elliptic curvatures can be caused to coincide with portions of every curve in existence, while there is not a single curve in any of the leaves of plants which admits of an equation, however graceful they may be.

The power of the lobated leaves in laying the foundations of new variety is obviously considerable ; but less use has been made of it : I need but name such extreme cases as those of the Thistles, and the *Geranium pratense* ; since it is fruitless, as it is here impossible, to pursue a subject of this nature in detail. And thence also must I be content with pointing out the new basis of variation assumed in the pinnated leaves, equally car-

ried on according to a plan, which is very definite under what botany terms decomposition to a third and fourth stage : while, when less regularly systematical, or when the division is intermediate between the lobate and pinnate, under a capillary form in the subdivisions, we obtain those almost inextricable outlines which we find in the umbelliferous plants, the Milfoil, the Adonis, the Matricaria, and many more.

But this, and all that relates to the fleshy leaves, in Cactus, Sedum, Agave, Mesembryanthemum and others, I must leave to the reader to pursue for himself ; contenting myself finally, with pointing out the accuracy and precision of the designs under which these outlines seem to have been wrought out. Nothing has been left to hazard, and there is no neglect : everything is neat, clean, precise, and free from errors or carelessness. It is generally also easy to trace a consistent symmetry, even in the smaller divisions and serratures of the leaves ; or they will be found to be portions of orderly curves, which a correct eye will easily complete through the entire leaf ; while a knowledge of this fact ensures truth and facility of delineation, with equal readiness in detecting the errors of artists in this department of painting. And although these plans of construction are most easily analyzed in the simple leaves, the same regularity of design will be found to pervade the divided ones ; while the whole offers a pleasing subject of analysis to those who are possessed of an accurate eye, and a knowledge of the geometrical curves.

If this imperfect sketch, thus selecting a single object, must suffice as a hint to be pursued by those who would study the inventions for distinction, not less than for variety, which are found in plants, I will not pass

from it without claiming the privilege of a slight digression on the subject of neatness or cleanness in this department of creation, and also on the same quality in the animal world; since I have nowhere else had an opportunity of pointing out one of the most striking provisions in nature, as it is also one which seems to have been nearly overlooked by naturalists, or viewed as if it was confined to a few animals. It will be seen, on the contrary, that it is one of the Creator's leading designs, and that careful provisions have been made for it, in both departments of life.

The contrivance for this purpose in plants, consists in the nature of the surfaces, most remarkable in the leaves, where this object is sometimes attained by a high polish and great density, at others by a waxy secretion, at others again by a minute texture of the surface, resembling that of hairs and feathers, or by means of actual down or hairs; as, in the flowers, the globular velvety surface which enhances the colours by dispersive reflection, serves for this end also. These prevent the lodgment of water, which is itself injurious, and, with that, of all liquid matters which might soil them; while the dust which might have adhered in a dry state, is easily dislodged by the first shower. How effectual the provisions are, is evident; since a dirty plant (to use an expressive term), is scarcely ever seen, peculiarly exposed as they are to the adhesion of soil: and thus does the vegetable world present that universal look of cleanliness and neatness, which is as striking as if there was a hand perpetually employed in no other office: preserving an order that we cannot maintain in our possessions, without constant labour. If all the dead portions, in leaves and flowers, with little exception, detach

themselves, the effect is the same, and so perhaps was the purpose ; while we know how disagreeable the appearance is, when, by housing them, we here interfere with the proceedings of nature. But if we overlook the contrivance as well as the intention, considering the effect, like all else, as a matter of course, so do we also, not merely forget to note another provision for maintaining the neatness of the vegetable creation, but neglect the very fact itself, as if this also could not be otherwise. Yet the least reflection will show that the result would be incredible but for experience. The simple power of vitality, maintaining the circulation, is not only sufficient to retain the feeble petal in its place against the power of the storm, but to maintain all the most delicate and tender flowers in perfect shape, rigidity, and order, during the time that they were ordained to last. We cannot imitate these objects, without much stronger materials, and ligatures, and gums ; yet the *Cistus*, with its almost cobweb petals of a few hours, is a structure of perfect strength, retaining the elegant form assigned to it, till the term of its life has arrived.

The same cleanliness, with the same decided intention to produce it, pervades the animal creation, and under many more forms than it is convenient or proper to notice. To man, it has been permitted to do what he pleases ; and he is not slow in disobeying the universal command, which the other animals have received through instincts for this purpose, and through provisions for rendering neatness attainable by them : as thus also has he contrived to make some of his followers what he too often is himself. And if we forget to note this also, we should certainly have found it a very difficult problem to devise the means of keeping all this

multitudinous world of animals in that state of neatness in which we find it some difficulty to preserve ourselves, peculiarly exposed as they are to soil. Yet a dirty animal, like a dirty plant, is scarcely to be found : the very Mole and the Earthworm, inhabiting the soil itself, are without a stain ; the Snail is clean, notwithstanding its adhesive surface ; the purity of the Swan, in the midst of its mud, is almost proverbial. In the birds indeed, we see a necessity for neatness, while we find the instincts as strong as the provisions are perfect. But in the terrestrial animals, there is no utility, nor does any inconvenience arise from the reverse ; whence we must conclude that the Creator's intention was simply neatness, order, cleanliness ; a virtue to which we are willing to give a place, in words at least, among the minor ones, as we term them.

In these, and in the birds, the essential provision is similar to that in plants ; consisting in the structure and superficial texture of hair and feathers. Popular prejudices term these animal substances less cleanly than vegetable ones : the facts are the direct reverse, as common experience in our own clothing should show. They do not absorb water ; and, like plants, they repel the adhesion of what is dry. Thus do the quadrupeds keep themselves clean with very little effort, as the birds do, under that pruning which they have been commanded to delight in : while, in both, the elasticity of these structures aids, as it does especially in the feather ; enabled to restore itself to order, very often, without pruning, however disturbed and soiled. Even the draggled train of the Peacock easily resumes all its beauty in the sun, with little effort on the part of the animal. In the insects, the provisions are often much

more striking. The most naked larvæ are always clean, like the earthworms, inhabit where they may. In others, a peculiar texture of the surface, like that of hair, produces the same effects; and thus do we find down, or hairs, as in the bee, the butterfly, and the caterpillars, preventing all adhesion of the several substances to which they are exposed. But as if to satisfy us of the Creator's decided intention on this subject, we find some of these animals provided with the very utensils of cleanliness which we construct for ourselves; furnished with brushes, together with that attached instinct of neatness which we daily see in use in the house-fly: while it would be easy to add much more to the same purpose, from the records of natural history.

There is yet more provided for the same end, if in a very different manner; though, in these cases, seeing that provision is made for the salubrity of the atmosphere and the waters, and for the feeding of animals, we easily overlook this second, if not secondary, purpose. In the following chapter, I have shown that dead fishes are rendered luminous, that they may be discovered and consumed before they become offensive. On the land, the consumption of carcasses is provided for by the instincts given to several beasts and birds of prey; and, beyond all, by the appointment of the different larvæ which are destined to this food: while to make that expedient availing, such is the produce, and such the rapidity of growth, as to have made naturalists remark that the progeny of three or four flies is sufficient to consume a horse. And assuredly for the same end has there been implanted in almost every animal that instinct through which they seek concealment when about to die; while how effectual this is,

we know, since with, I believe, the sole exception of the shrew mouse, often choosing a gravel walk for this purpose, we scarcely ever meet the dead body of a wild animal.

Even this alone does Creation teach us of the Creator's will, when we are inclined to study it as the display of His mind and the declaration of that will: informing us of laws which He has made, but which are not among those that He has revealed in words. Or if there is one who will not look at nature in this light, he must at least be struck with the picture which I have here placed before him, involving all the organized creation, and even the inorganic world. The soil, the rocks, the sand, the surface of the earth is everywhere clean, or there are provisions for rendering it so when it has become foul: it is under the influence of man alone that we must seek for the reverse, as it is beneath his interference that we find all the disorders of creation.

To return to my subject, I may point out a few peculiar inventions in the general forms of plants, as I did in the case of animals, while the inferences are the same; though I need not here suggest where the utility and the contrivance are inseparable, or where the former is dissociable from the peculiarity. The reader will easily perceive this himself; as, to the few and familiar examples which I must needs select, he can add hundreds, under the least knowledge of plants, and thus become sensible of the resources of invention displayed in the vegetable world.

Such is the tribe of Cactus, under a capricious variety of forms sufficiently familiar, independently of the singularity of the fundamental principle, where we

often know not what to term leaf or stem, united to a splendour and variety of flowers not exceeded anywhere : while the flagelliformis and the mamillaris approach the very bounds of incredibility. To name *Stapelia*, *Aletris*, *Aloe*, *Euphorbia*, *Cotyledon*, and *Mesembryanthemum* after this, is perhaps to descend in the scale of singularities ; yet many of the species in these will afford ample room for the same reflections.

In our familiar plants, the Furze is scarcely a less singular invention ; nor is that less true of the Broom, if the perpetual sight of such plants causes us to overlook their peculiarities. The *Spartium junceum* is even a greater caprice of nature, since it is a shrub constructed out of rushes. Such is the *Cuscuta*, an almost leafless fibre ; and such the *Orobanche* and the *Lathræa* ; being little other than spikes of flowers, without leaves or stems, and the former without roots, trusting to others for the place which they cannot make for themselves. The simplicity of the whole contrivance in the *Lemna* is an exhaustion of the structure of the ordinary flowering plants ; and the two-leaved *Exacum* is scarcely less contrasted with the interminably proliferous *Tussilago* and the complicated Oak. Thus do we find, among our own plants, specific inventions for the unexpected purpose of entrapping insects, in the glutinous *Lychnis*, the cobwebs of the *Arctium*, and the leaves of the Teazel ; as our own *Drosera* is outrivalled in this, by the well-known *Dionæa*, and as the former is by the *Nepenthes* and the *Sarracenia*, among the most singular of the contrivances in the vegetable world.

If the Ferns and the Mosses present us with two new and fundamental inventions, followed by an endless variety of subsequent contrivances, it is a field which I

cannot pursue. The Lichens are infinitely more striking, since they scarcely offer any points of resemblance to the great world of plants. They constitute a pure and independent invention, almost more remarkable than any which occurs in the animal creation; when we cannot say that they have either leaves or stem, when they are sometimes without root, or when all the parts are the same, resembling neither, and when also they are without flowers, as we cannot discover their seeds. But here too must the reader follow the endless variations made for the species, from the membrane or dust which paints the rock and the bark of the tree, to the long entangled strings which dangle from it, and the beautifully branching shrub which covers our heaths.

The inexhausted invention is again displayed in the never-ending Fungi, differing from all that has preceded; while even organization itself seems about to disappear at last in the Tremella, as, in many others of firmer texture, the seeds alone seem to constitute nearly the whole plant. And even under these extremes of simplicity in form, we discover a power of variation which could not be believed; as in that also we can conjecture no possible purpose, where all serve but for one end, the food of a very few worms and snails. It is not so much the diversity of invention, in the families of Boletus, Agaricus, Clavaria, Peziza, and so forth, which strike us, as the efforts used in varying a single family, such as the Agaric; where the possibility of variation seems exceedingly limited, and where, nevertheless, the species amount to hundreds. It is the problem of the Medusa, executed under much greater restrictions; since there is nothing superadded for the sake of variation, to a structure which is fundamentally

one of the most simple. Even beauty of colouring has not here been forgotten ; since we find in this single family, every brightest colour which the rainbow can show, with endless others of humbler pretensions ; while this beauty was certainly not appointed for the blind animals which feed on those plants.

The remarks which I formerly made on the shells apply equally to the submarine plants. It is a little vegetable world apart, replete with purposeless variety and beauty, in forms and colours ; otherwise than as the purpose may regard us. The exquisite care in the constructions, with the grace and the designs of these plants, are not exceeded by anything among the terrestrial ones ; as, in artificial intricacy of symmetry, they have scarcely any rivals, even in the complicated leaves of the umbelliferous plants. I need not name individual examples, since they are well known even to those who are not botanists ; though I may remark, that here almost alone, in the transparent *Confervæ*, we find those beautiful and varied internal mechanisms, where we must at least admire the invention, since we are yet ignorant of the purposes.

The resources of invention which have been displayed in the forms and colours of flowers will be still more striking ; while the familiarity of these render them a more acceptable illustration than what has preceded. I need not repeat what I formerly observed respecting their superfluity, as utility is concerned ; while the great care bestowed on their colouring, not less than the contrivances under which their forms are diversified, bespeak the intention to produce variety of beauty, much more decidedly than in the several ornamental animals, since no collateral purposes can be served in

this case. It is possible indeed, that a few of the birds and insects may derive some enjoyment from these objects; but no extravagance of supposition can allow much to have been intended for them.

It would be far too long here, to trace these inventions through the adoption of certain fundamental contrivances and their subsequent variations; as it is also what any botanist can do for himself: what I suggested formerly respecting the *Didynamia*, is an example easily pursued through all the other essential forms. It will be better that I point out a few of the unexpected and peculiar varieties in this department; while those will easily suggest many more. If the symmetrical flowers, whether monopetalous or otherwise, evidently demanded the least invention, it will be seen that even here, the contrivances for variety are often sufficiently unexpected, as they are often also such as a human artist would not have divined, ever ready as we are to forget this, in seeing what has been done. The *Didynamious*, and still more the papilionaceous ones, lead to very different conclusions; as, above all, do the compound flowers; emulating so exactly a simple polypetalous one, that it is only a botanist who knows what the contrivance really is. If a less striking circumstance, I may also point out the umbelliferous ones, with many of the corymbose and capitate, where the general effect of a single flower is often given to a crowd, by prolonging the petals of the outer ones in the group, or by condensing many into one mass, under various modes; *Scabiosa*, *Iberis*, *Hydrangea*, *Ageratum Mexicanum*, and many more.

Taking genera instead of classes, or species in those genera, since I am not about to pursue the plans in this

place, I may suggest the singular variations produced, chiefly by the division of petals, in *Mignonette*, *Schizanthus*, *Clarkia*, *Lopezia*, and the *Lychnis flos-cuculi*; those produced by inequality of petals chiefly, in the *Violet*, in *Lobelia*, in the *Geraniums*, and in the *Amaryllis formosissima*; that which results from the conspicuity of the small parts, in *Hypericum*, *Myrtle*, *Melaleuca*, *Protea*, and *Mimosa*; and again, the effects produced by the obliquity and the reversals of the petals, in the *Begonia*, the *Vinca*, and the retroverted *Lilies*. The long tube of the *Mirabilis*, the pockets in the *Cypripedium* and *Calceolaria*, the seed-vessel in *Nigella*,⁵ the cells for lodging the anthers in *Kalmia*, the closed mouth of the *Antirrhinums*, the curved tube of the *Aristolochia*, are other examples of singularity:¹ as are, still more, the remarkable petals of the *Hoya*, the strangely contrived *Euphorbia*, the singular, and often varied cone of the *Arum* and its resemblances, and, above all, that extraordinary invention for the *Iris*, which departs from all analogies. And if, with these, I name the *Rafflesia*, a flower without a plant, and of such enormous dimensions, it is to point out an invention in this department, to which I cannot perceive any parallel in the extraordinary contrivances for the animal world.

But the design to produce variety is perhaps even more marked in those flowers which possess parts in addition to the prevailing structure: while if these have been termed nectaries, it appears that many of them do not produce honey; when not doing this, we can see no purpose in them, but that which is here under review, while the honey also might, in each case, have been produced at the insertion of the petals, as it is in

the greater number of flowers. Hence the singular inventions in *Passiflora* and *Parnassia*, the cup of the *Narcissus*, conferring so distinct a character, the peculiarity of the *Columbine*, the remarkable spur of the *Impatiens* and many more, a large portion of the singularities of the *Orchideæ*, and the very striking contrivance in the *Aconite*. But there is nothing perhaps so inexplicably remarkable in flowers, as the imitations of animals which some of them present: too accurate not to have been intended, in whatever light we may view that intention; while the deviations for this purpose are far from being trivial ones. This is familiar in the *Delphinium elatum*, representing a bee seeking its food in the flower; but still more striking in the well-known *Orchideæ*, mimicking even to the lizard, under the extraordinary prolongation and division of its long lip; and in the strange configuration of the *Mantissa saltatoria*.

If the marked intention to produce variety and beauty in flowers, by means of colour, can admit of no doubt, we can see, in the first place, that there was no necessity for the peculiar structure of a petal, much less for any colour; as I have indeed shown that there was no necessity for any petals.* There are numerous flowers, in which the petal resembles the calyx, both in colour and structure: while a decided intention to produce beauty, on the other hand, is shown by the colouring of the calyx as well as the petals, in the *Pomegranate*, *Fuchsia*, *Polygala*, *Hydrangea*, *Fumaria*, *Tropæolum*, and many more; as, in *Salvia horminum* this design is carried so far as to colour the bracteæ, as is also done, if less conspicuously, in the *Ajuga*, in *Lavender*, and in many others; while in the scarlet *Salvia*, even

the footstalks are coloured like the calyx and petals, so as to render the whole one blaze of red. And when we find plants in which the flowers so far exceed in quantity or aggregate bulk, the stems and leaves, as in *Humea elegans* and many more, that it seems all flower, as the *Rafflesia* actually is, we cannot help drawing the same conclusion respecting the intention to produce beauty, while in such cases as these, it may possibly be the only object.

If I have been obliged to notice hereafter the intended production of beauty in the colourings of flowers (c. 47), showing also the principles applied to this purpose, I may here point out some of the leading facts which relate to variety of invention ; trusting, as before, to the reader to fill up a necessarily slender indication. If the prismatic colours form the obvious point of reference for the inventions in uniform colouring, we find all those tints in flowers, in absolute purity and also under mixtures and degradations which only stop at the lower and unpleasing tones ; as if under the conviction that all the beauty of simple colour was there at an end. There are not many drab-coloured flowers, though *Cheiranthus* and *Hesperis tristis* are exceptions, as are a few more : while, though there are some disagreeable browns, as in *Atropa belladonna*, the far greater number are always rich in tint, and the little black which has been adopted, is also rendered pleasing by contrast.

White, I need not notice ; and I have pointed out, in the chapter on Beauty, the peculiar source of its purity and splendour. Beginning with the dull reds of *Zinnia* and *Potentilla*, we trace this through the *Salvia coccinea*, the *Celsia*, the *Poppy*, the *Lobelia cardinalis*,

and the *Geranium inquinans*, up to that scarlet which the eye can scarcely endure, in the *Verbena milindris*. Under orange, we find the several tints of the Marigold, the *Potentilla*, the *Buddleia*, the *Lily* of this hue, and the *Ipomæa*; while, if here sometimes proceeding from scarlet, they pass through all the yellows, in *Tropæolum*, *Crysanthemum segetum*, *Broom*, *Jonquil*, *Hemerocallis*, and an endless number more, till they terminate in the evanescent tints of the *Primrose*. If green is the rarest hue among flowers, we still have it in the *Ixia* and in the cultivated *Auriculas*: but of the varieties of blue there is no end; commencing in absolute purity, in *Borago* and *Myosotis*, passing towards purple, in *Echium* and *Vinca*, and verging towards grey in *Plumbago*. The purples and crimsons are unbounded in variety, while, for the most part, disdaining all reference to the prism; as the examples are overwhelming, in the *Pansie*, the *Rhododendron*, the several *Heaths*, the *Sweet-william*, the *Pinks*, the *Roses*, and the *Amaryllis*, among others: including the splendid crimsons of *Cactus* and *Mesembryanthemum*. In black and brown, it suffices that I notice the *Aristolochiæ* and *Stapelieæ*, the *Lotus tetragonolobus* and the *Tagetes*; while for the most part, these colours are but partial, and used as contrasts, or for the production of painted patterns.

But it is perhaps in this pattern painting, that the design strikes us most forcibly: they who love to cavil, might not easily find here necessity, contingency, or carelessness. The designs indeed are not so artificial as those in the *Chætodons*, nor can they be compared with those in the butterflies; yet there is no want of variety, as there are instances also of that mathematical regularity which I formerly pointed out in some animals;

as in the tails of some of the *Monoculi*, and as occurs in a new fish, to which I have as yet given no name. Where this painting follows the mechanical disposition of the parts, or the fibres of the petals, as in the *Tulip*, it is perhaps least striking as a work of design ; because it might then be thought scarcely intentional, by those who are unwilling to see intentions ; and thus might it perhaps also be judged where it pervades the whole petal. But we cannot judge in this manner of that inscription on the *Larkspur* which attracted the attention of ancient poetry, nor of the patterns on the *Geranium cucullatum*, nor of the little black pencillings on the *Pansy*, marking such minuteness of attention, nor of the painting of the *Euphrasia*, the *Stapeliæ*, and the *Iris*, nor of the red and yellow sprinklings on the petals of the *Saxifrage*, superficial as if they had fallen from the artist's brush. And if I might seek examples far wider, it must suffice that I point out the designs on the *Fritillaria* and the *Tigridia pavonia*, entirely at variance with the structure, and as artificial as can be well imagined.

If the inventions for variety of odour in flowers would have equally deserved a place here, I have noticed the general fact of invention in a future chapter, together with its object, being our gratification ; it must suffice here that I point out some of those peculiarities which bear a resemblance to the caprices in the *Orchideæ*, since an enumeration of all the distinct odours would pass all reasonable bounds. It is among those peculiarities, to find the same odour, either identical, or under slight modifications, allotted to many different flowers : since we have abundant proof that there was no want of inventive power. This is the case with the *Jonquil*, the *Narcissus incomparabilis*, the *Coronilla glauca*, the

Hemerocallis flava, the *Spartium junceum*, and the *Trollius Europæus*, all coinciding very nearly, while also mimicked by one of the *Agarics*. Such is the coincidence between the odours of the *Jessamine* and the *Calycanthus præcox*, between the *Gardenia* and another *jessamine*, between the *Heliotrope*, the *Tussilago fragrans*, and the *Hesperis tristis*, between the *Verbena triphylla*, the *Lemon*, and the *Geranium citrifolium*, and between *Scandix cerefolium*, *Anise*, and *Artemisia dracunculus*; while the *Geraniums* are the wide mimics of many plants. The imitation of animal odour is found in *Mimulus moschatus*, and in *Geranium molle* and *moschatum*: and that of mice in *Cynoglossum*: while the smell of the hog is mimicked by *Athamanta*, *Melilot*, *Phlox*, *Trigonellaa*, and *Gnaphalium*.

In proceeding to the subject of invention and variety under the mineral kingdom, I need scarcely repeat, that these concern man alone; while instead of selecting subjects for remark, I must content myself with referring to the mineralogical knowledge of others, or to the collections of those substances, of which all enumeration would be unavailing. In distinct and designed species, the forms are as yet unnumbered: in variety of aspect, they may safely be termed innumerable. But it is first necessary to prove that they are not accidental substances, but were intended to be what they are, under special designs for that purpose.

Whatever might be said of the mineral compounds and forms, it must at least be plain, that every simple substance is a distinct invention and design on the part of the Creator: while the intention might be argued from the uses not less than the peculiar properties; as I

have done in a future chapter. In the next place, there are two sets of laws, under which the forms of minerals are produced ; or, at least, we are compelled to consider them at present in this light, not well seeing the connexion between the simple laws of mere chemical combination and that which produces geometric forms in substances ; acting in simple bodies, as in the metals for example, just as it does in compound ones.

Now, of chemical combination I have elsewhere shown, that it must be a branch of design, because every chemist knows that he can produce whatever compounds he pleases, so fixed are its laws, that there is no accident under his hands—that he can assign the cause of whatever occurs, or, failing to do this, seeks for it with the conviction that it must exist. Thence can the Creator no more be ignorant of the meanest mineral, than He is of water or of the atmosphere ; while admitting that He appointed these, we must equally concede that the former are His inventions. In the case of crystals, the mathematician is compelled to argue in the same manner as he does respecting the laws which maintain the planetary system : there must have been a design, when he is himself able to pronounce on the shape of the crystal which he has not yet examined, or to foretell what will be the forms of those which remain to be discovered. He could not have calculated these, unless the Inventor of all those things had done so before him.

It is in these inventions therefore, perhaps above all others, that we see the pure intention to produce variety ; since, as I originally showed, there are no collateral purposes in the vast majority of them ; while this demonstration of the Creator's resources is neces-

sarily directed to us. How much beauty has been lavished on them, I need not say to those who know those substances: the varieties in copper alone, may be compared with the flowers and the butterflies. In this department also, there is boundless licence as to the individual forms, there are no laws of organization to prevent endless mixtures and approximations, and no rules to prevent what we may safely term accident from producing those variations to the eye, which far exceed what the other divisions can show, and which may safely be considered interminable.

I need but suggest further, the varieties in the compound and coloured rocks, such as granite and marble; though I ought not to end this chapter without reminding the reader of the diversity of organized bodies, in both departments, which are now found in the mineral form. These appertain to the zoology and the botany of former worlds; while, differing as they do from the corresponding objects in the present, they serve to enlarge still further our views of the inventive power of the Creator.

CHAPTER XXVII.

ON THE LIGHT OF THE MARINE ANIMALS.

IF I have thought that the mysterious agents of the universe peculiarly demanded a place under the present attribute, so have I chosen this division for such facts in creation as are least conformable to its general course, and for those also which particularly strike us from the apparent difficulty in the execution ; judging of this by our own knowledge and powers. The fact which I am here to notice, possesses every claim on this place. If the nature of the agent, under all its forms, is unknown, it is here peculiarly obscure : and there is a necessary purpose attained, by means quite different from those through which it is, otherwise, universally pursued. It is, in every sense, unexpected : and I know of nothing which affords a more striking example of that resource and power which are never at a loss ; which, in producing a difficulty, have also appointed means for surmounting it, or when an evil has arisen from a general law, established a special one as a remedy.

That every preceding writer on Creation has overlooked this great fact and its uses, is a proof how little the universe has been studied as it ought to have been. Nor have mere naturalists been less negligent. If they had remarked some examples of it, they have not only stopped in the pursuit, but doubted or denied the uni-

versality of the law, as they have been utterly unaware of the purpose. Thus, for want of a leading principle, they have regarded the facts of this kind which they have noticed, as insulated things, and of a trifling nature : and such will ever be the fate of natural history under the same want of reflection and investigation. I have frequently shown in this work, how the neglected facts of nature often acquire a high value, from a particular mode of contemplation ; and the present is an instance in point. To know that some marine animal was luminous, or that the sea emitted light at times, was a mere fact, connected with nothing : or it was ranked under the term phosphorescence, among many others, which, under an obvious common appearance, were entirely distinct in their real nature and their purposes. And the other explanations offered have been no less idle, and equally discreditable to philosophers. Ever anxious in causation, and preferring even unmeaning words to the more useful confession of ignorance, they have referred it to electricity, to friction, to the absorption of light by sea water, and to the presence of a visionary luminous oil : while even Boyle, with less labour of thinking, calls it a “cosmical law of the universe.”

If thus easily has philosophy been accustomed to satisfy itself, let me make one remark at least, because of its universal importance. I have said elsewhere, that the consideration of final causes is of the utmost value in science, as it is often our only clue to the generalization of insulated facts. I do not claim merit for myself, but for the principle, in saying, that it was here, as on many other occasions, my own guide, and that hence, with the utmost facility, was the universality, as

well as the real nature of this great fact, so long the disgrace of natural history, established.

That I have no work on this subject to refer to but my own, is a reason for making the present details fuller than I should otherwise have done: and if I state the general purpose before pointing out the facts, it is because the desired impression is thus best attained.

Light diminishes rapidly in passing through water, as it does in glass and other transparent bodies. At a certain depth, the sun itself would be invisible, as if a plate of iron had been interposed. Experiments have been made to ascertain what thickness of water excludes all light; but as yet without success. Bouguer's trials had fixed this point at 723 feet: but his process was radically erroneous. Nevertheless, the diminution of intensity takes place in so rapidly increasing a ratio, that we can have no doubt respecting the absolute darkness of the depths of the sea; while if we double his estimate we may not be far wrong. But while these estimates refer to the full light of the sun, and as the light of a cloudy day, of twilight, and of night, are successively far inferior, there must be many and long periods in which darkness reigns at very small depths, since the quantity transmitted is proportioned to the intensity.

It is also familiar, that many fishes reside in the deeper parts of the sea, as is true of the Ling among others, and on the bottom, as occurs in the flat fishes; while, moreover, many are nocturnal, sleeping in the day, like the beasts of prey, and seeking their food in the night. On the land, absolute darkness is a very rare occurrence, while the nocturnal animals have a peculiar provision for discovering their prey, in a large

pupil and highly sensible nerve. But under the entire want of light that must often exist in the sea, no such power could be a compensation : while in minor cases, the great velocity of these tribes, and the frequent consequent distances between the pursuer and the pursued, must also be an obstacle to distinct vision. Under any view, it must have been impossible to prey at night : since our own least visible light must be pure darkness, even near the surface.

Here then is a world without light, the habitation of myriads of the most active and rapacious animals of creation : often social, performing various functions, moving over great distances with the rapidity of birds, and, above all, provided with organs of vision. Did naturalists never reflect on such a world, or ask themselves how such pursuits were carried on in utter darkness? They had not thought on the darkness alone of that world : and when they knew it, and did not inquire how the inconvenience to its inhabitants was remedied, is it not because they too often forget to view creation as they ought, to inquire of intentions and final causes, to look higher, and think more deeply of Him who has neglected nothing essential to the good of His creatures? Such views would at least have led to the requisite inquiries : and the purpose, like the universality of the fact, would not have remained till this day to have been pointed out. The cultivators of this science would be less pleased at any other explanation of their neglect or errors : yet if I have offered this one, it is not for the purpose of censure, but that I might show, by one striking example, the value of these Higher references in the study of natural history. He who sees God, wise, beneficent, and governing, will find, in more cases than

this, a clue to his studies, and the solution of his difficulties.

A remedy for the interception of the sun and the absence of light, was wanted : day could not be brought into the depths of the ocean, for the laws of light forbade it : yet, to at least the mutual pursuit of its inhabitants, that was indispensable. It remained for Him who created the difficulty, to invent the remedy. I do not say that man might not have suggested it, though he seldom recollects that he knows nothing but what creation and its Creator have taught him,—often also apparently teaching him as specially as the insect, on whose instinct he looks down with contempt, while priding himself on his superiority of reason. But even if he could have imagined the remedy, it was boundless power alone that could have furnished it. And the Creator has done this by means, the nature of which we cannot comprehend ; yet not more ignorant here than in all other cases of that local production of light, independently of the sun and of combustion, to which the vague term phosphorescence is applied.

The never-failing wisdom and power of the Creator have established an independent source of light beneath the ocean ; and it has been disposed in the precise manner required to answer the intended purposes. The animal itself was to be seen amid utter darkness ; and it is rendered luminous, or becomes, itself, a source of light. Nor, whatever other analogous cases may exist in the several phosphorescent substances, where we can see neither connexion nor object, can we doubt the design and the purpose here, when we find the provision universal and the purpose necessary, and when we also can conjecture of no other mode in which it could have

been attained. The great pursuit of all animals is food, and the food has here been rendered luminous, that it might be discovered. But for this provision, the deep-residing fishes could not have found the means of existing at the bottom of the sea, and the night-preying ones would have been for ever helpless: while my own investigations have shown, that there are predatory kinds immoveably fixed to the bottom, at depths of 6000 feet, where darkness is eternal.

The truth of this view is confirmed by the effect of luminous bodies on fishes. Even in ordinary day-fishing, it is a brilliant object, not a definite form, or a fish, which is the subject of pursuit, and it is so especially, as might be expected, among the swift fishes. It is the bright silvery skin of the bait which is the attraction, and familiarly so in the mackerel, equally ready to seize a shining piece of metal or a brilliant feather. Thence also the use and effect of nocturnal lights in fishing: well known to our remote predecessors among the ancients, to the inhabitants of the Mediterranean, and even to savage nations; all profiting by that knowledge which we disdain or neglect. If adopted in the fraudulent salmon fishery, and there only, no one seems aware that the light, supposed to aid ourselves in seeing the fish, is in reality its bait, if I may use such a term. It is the object of pursuit, because it is the expected prey.

But this is not all of the Divine contrivance on this subject: while if the object is the same,—the discovery of prey by the means of light, the mode of attaining that end is different, as there is some difference also in the nature of the prey itself. How far the chemical sources of the light may coincide or differ, we do not

know: but the one at least belongs to vital action, while the other is engaged with dead matter. If naturalists have hitherto confounded the two, it is not surprising under their neglect of this subject, and under the use of terms as a substitute for knowledge. Yet viewing this latter fact as I have done the former, we see two exertions of wisdom, and two objects, similar but distinct, gained by two specific efforts of power.

In all the living marine animals, the light is brilliant, often of different colours, commonly confined to a certain portion, or organ; or, at furthest, to the surface, under the command of the will, and dependent on life, since it disappears at the death or capture of the subject, as the interior parts also show no signs of it. But shortly after death, the whole body becomes luminous, displaying a pale uniform light; while the luminous matter can be detached and diffused through water, which the living light cannot. This fact is familiar in our larders; and though commonly attributed to putrefaction, it commences long before this process, and even ceases as that is established. And if the purpose of this second contrivance is plain, so ought it always to have been. The dead animal, in this condition, is still food: by putrefaction it would be wasted, and might be injurious, as such matters are, in the atmosphere: it becomes an object of attraction under this new expedient, as it had ceased to be, in losing its former powers of producing light with the loss of its life. And the wisdom is not less shown in conferring this new property anterior to putrefaction: since it is then more valuable as food. Here again we see the utility of final causes in the discovery of truth: since natural-

ists had always considered this as a mere result of putrefaction, and thus given a false view of a fact in nature, from neglecting its Author.

If this includes the essential course of reflection and of inference on the subject before us, I may prolong this chapter by a few further details, for the interest or instruction of the reader.

Of the living lights we are even more ignorant than of the dead ; since we cannot detach the luminous substance, if there be one, nor discover the organs by which it is produced. In the larger fishes, it seems to exist over the entire surface, as it is evidently the temporary produce of an act of volition ; though it is not easy to judge correctly of the facts, as it is possible that the light around them may, partly at least, be produced by the disturbance of minute animals in contact with them. This however will not of itself explain the appearances : since, in that case, it should attend every movement, whereas it is but occasional, and is excited, among other things, by a noise or an alarm. And if I already said that the luminous property does not belong to the water itself, we are assured of this, by finding that it never exists unless animals are present ; while if the crowds of the nearly microscopic ones are the cause of that general light which seems to have given rise to this error, so does it require an equally minute investigation to detect those hitherto almost unsuspected myriads. Seamen, knowing the difference between blue and green water, know also that the former very rarely contains such animals, and is as rarely luminous. With some noted exceptions in the ocean, it is on the shores chiefly, that we find highly luminous water prevailing.

I believe the power of producing light to be an universal property in the marine tribes, on the general grounds already stated : but that belief is confirmed by the fact, that I have never found a species, however microscopic, in which it did not exist. I except the shell fishes however ; and if there are obvious reasons why the display should there be difficult, so must I plead ignorance of what is of no easy investigation. Yet the *Pholades* are known to be luminous, and the places of others are generally marked out by luminous parasites. But in all other of the marine animals which are not fishes, from the largest *Medusa* or *Holothuria*, down to the most minute *Beroe*, *Cyclops*, *Vorticella*, or *Vibrio*, there seems a particular point, or organ, adapted for this purpose, which, however, we cannot discover, as the light which is our only guide for it, disappears in that which is necessary for its examination ; as also we cannot find any organs in many of these, beyond the stomach and ovaria, and the tentacula or other appendages. And the reason for this conclusion is, that in a *Medusa* of a foot in diameter, the light will sometimes not exceed a pea in size, though in others, as in the *Cyclops* very often, its brilliancy causes it to appear larger than the whole body. If I formerly said that the colour of the light varies, I may add that it is sometimes snow white, or else of the electric blue, or of a greenish tinge, or reddish, or yellow, or even scarlet.

Such then is the true source of those often brilliant, sometimes terrific appearances, so frequently observed at sea. Above a shoal of fish, an alarm will often excite a sheet of fire resembling submarine lightning. In the tropical regions, the surface of the sea sometimes

resembles a plain of snow, from the same cause. The flashes occasionally seen under the water, are produced by the larger fishes ; and the line of light which attends the descent of a rope, is caused by the disturbance of the minuter animals. The twinkling stars so common on our own coasts, are generally the produce of *Medusæ*: and whenever a light is lifted on an oar, it is easy to secure and examine the animal, so as to satisfy ourselves of the cause : while if that is as easily done on sea weeds, or shells, it is the more surprising that any mystery should ever have existed on this subject. The fearfully luminous appearance of the sea in storms, equally arises from the crowds of these animals thus brought to the surface and kept in a constant state of agitation. Nor let the universality of this light, in any case, excite surprise. Had the water been examined, as it had not, we need not have supposed itself to be luminous, when it will be often found so teeming with life as to be turbid, as if from diffused sand.

But, quitting details which I must not here extend, I may conclude with one further general remark, though appertaining to the attribute of Beneficence, and thence slightly repeated in treating of the defences of animals. Inasmuch as the lights are an enticement to the pursuer, the whole effect, to the pursued, would be evil, were it not for that compensation which seems never wanting. The light is under the command of the animal ; and the defence is, to obscure it. This is easily ascertained in those which we can separate and detain. If much irritated, or alarmed by the disturbances of the water, they extinguish the light, though it had long been shining steadily ; while, when again producing it, a far slighter alarm suffices to obscure it, as if

they were on the watch ; as, after a repetition of those, it is permanently extinguished. This is obviously an instinct of defence, arising from the knowledge that obscurity is safety. If any of those animals are excited, by a needful curiosity, to display their lights, or if those are used as a guide for their own pursuits, as seems to be the case with the larger fishes under alarm, I know not that there is sufficient experience to determine this point. But it must not be objected to the preceding views, that the lights in question cannot serve the asserted purposes to the inferior marine animals, inasmuch as many are without eyes. Eyes are now known to exist in very many which were long supposed to be, in many other respects also, of a more defective organization ; and even where they are assuredly wanting, as in the *Medusæ* and *Beroes*, there is a perfect sense of the presence of a luminous object, since they pursue a moving candle as correctly as a fish could have done, and will crowd round the single opening for the admission of light which has been left in a darkened vessel.

CHAPTER XXVIII.

ON THE MODES OF MOTION IN ANIMALS.

THE subject of the present chapter is analogous to that of the two first in this division. It attempts to point out variety in action, as those detailed varieties in form : while if evincing resource and power throughout, that Power seems occupied, in the last cases here quoted, in the same display of invention which it has shown in the forms of the animals. In addition, it bears a reference to the mechanisms formerly indicated, by showing their applications ; as it is, further, somewhat connected with the subject of the 53rd chapter.

The ordinary motions of man and the quadrupeds, in walking and running, are familiar ; but in each case, simple as they may appear, the anatomical and mechanical analysis is far too intricate, and would be much too long for this place. But the reader of the least observation can perceive how exactly the velocities have been adapted to the inclinations and pursuits of the several animals, how peculiarities of motion have their several uses, and how all these have been provided for in those mechanical arrangements, of which I formerly noticed such as I could afford ; while he who desires to know all that natural history can teach, must read and examine far more widely

The simplicity of the motions and actions, in the

birds, under walking and running, renders it unnecessary to notice them. But I may point out the great velocity in the Partridge, the Rail, and others, with the far more remarkable power of the Ostrich, and, reversely, the slow and difficult motions of the aquatic birds. The former are a substitute for flying, under the intention of concealment or escape : in the latter case, it is easily said, as it has been, that it was impossible to combine the forms necessary for running and swimming in the same structure. This is one of those false views of creation which we find pervading the writings of naturalists, everywhere ; the result of ignorance which does not know what is effected, and of vanity conceiving nothing possible to the Creator which is impossible to itself. There are far greater difficulties than this, surmounted everywhere, as I have often here shown : the true reason is, that a more active and perfect motion on the land was not required. Or if anything of this nature should really be impracticable, as being self-contradictory, the wisdom and resource are equally shown, in rendering it unnecessary, and in preventing the animal from desiring it. The imperfect power of the quadrupedal amphibia on the land, admits of similar remarks. Their true element is the water, since it contains their food : we must not imagine wants and situations, neither impressed nor designed, and then decide on imperfections.

The walking and running of Insects offer a much more complicated subject, from the great diversity of the structures in this numerous race, and from the great differences in their velocities, their modes of action, and the surfaces and substances on which these motions are performed. Taking, in a mass, the animals usually

classed under this popular term, the utility of the prevailing number of six legs becomes apparent, from the frequent use of the front and hinder pairs, as hands. But, as I formerly had occasion to remark, we do not see why an Iulus should possess more legs than an Earwig, especially when no rapidity is gained by this large number. Or, approximating these with the caterpillars, so as to consider the motion to be that of creeping rather than walking, we are even more at a loss for the reasons, when we find such differences in number as those that occur in even a single genus: seeing also that the Centipede with a hundred and ninety legs has no advantages above those possessing a much smaller number: as these many-legged animals also are often not more rapid than the worms which have none. Variety of design is, as I have already said, the only reason we can see, at least as yet.

In this great tribe, among much more, we cannot but be struck with their several powers of surmounting ground, or surfaces and forms of so many different kinds as those with which they are engaged; especially when, to so many, a grain of sand is a rock, and the down of a plant a forest. But while their small weight aids them against the resistance of gravity, so do their enormous strength, and those several provisions in the feet, consisting of claws, and machinery to form a vacuum, some of which I formerly noticed. And the same strength, united to their hard external coverings, protecting them from all injury short of destruction, enables them to force their way through obstacles which no other structure or power could encounter. But not to notice more of these facts, it may suffice to point out the rapid mo-

tion of a fly on glass, where a vacuum in each foot must be formed at every step, and that of a spider on the apparently impracticable threads of its web. Of their power in these actions, many of the beetles afford examples, since they can walk under considerable weight ; as the ants and many more prove their indefatigability with their strength, in their perseverance, and in the force which they exert. And the velocities are in some cases scarcely credible, when we see the length of the legs, and endeavour to compute the necessary rapidity of their action. The red spider of the strawberry (*Gamasus*), seems almost in two places at once, as if flying rather than running : and the naturalists also inform us of a fly whose steps they have computed at a thousand and eighty in a second, traversing in that time a space of six inches.

If the Crab walks and runs with great velocity, either on the land or beneath the water, there are motions, here, and in other tribes, which it is not easy to designate justly ; as indeed those of walking, creeping, running, and jumping, are not always to be separated. The motions of the water Spider, the water Beetle, and some water Cimices, are among those, as some of them might rank under swimming ; while, under any term, they are sufficiently remarkable. Those of the Echini and the Asteriæ, on the submarine soil, even surprise us more than the walking of the centipedes, when we see the enormous apparatus, formerly described, for the production of so small an effect. The *Asteria* abounds in feet, such as they are, to little purpose, as do some of the *Holothuriæ* ; and the *Echinus* to still less, when, in addition to a leg in every spine, it has also a provision of

membranous feet, yet, with all this mechanism, is not, as I formerly observed, more rapid than the snail which does not possess one.

If the motion of creeping is but a mode of walking, the variety which it presents, with the contrivances sometimes provided for it, require that it should be separated as far as it can. In the quadrupeds, it is only remarkable for the power of insinuation and surprise which it affords; as it is provided for by a long and flexible body with short legs, in the Weasel and Ferret, and by the former alone in the Cat race. It is necessarily also the motion of those which burrow; as, in each case, its utility is apparent. In the Serpents, it is the sole mode of motion; and is thus also a distinct one, since it is performed without the aid of legs. In this instance, the fore part of the body is rested on the ground while the hinder is brought forward; as, for the former purpose, the abdominal scales can be partially erected, so as to take the firmer hold. The ribs also move so as to aid the scales in producing motion; the hindermost ribs, which pass beyond the lungs, having no other use. The more rapid motion of serpents is effected by vertical curves like the geometric caterpillar. The spring is caused by the unwinding of a spiral or by the straightening of a curve, as fishes and some maggots move in this way on a smaller scale. These animals can also advance by an undulation parallel to the plane; and, in this case, the effect is produced on the same principle as swimming, which will be explained hereafter.

The same principle and mode of motion is largely applied to the worms and the larvæ, but under many varieties of construction and action; insomuch that there

is a kind of transition from the more proper walking of the centipede to the pure serpentine creeping of the earth-worm. The caterpillars belong to this class : but under a variety in the lengths, numbers, powers, and shapes of the feet, which I need not here detail, while their frequent velocity is well known. Yet I must notice some of the peculiar inventions for aiding these motions, in jaws, or hooks, for fixing the anterior part of the body, in spines near the tail, for securing that part, in adhesive secretions, like the snail, in an adhesive power in the foot or tubercle, apparently similar at times to that in the foot of the fly, in claws, cushions of hair, or brushes, and in the production of silk ; under all which they attain that power of climbing over all substances and surfaces, which we see in daily use among these animals. If some of these larvæ spin and lay a highway of silk for themselves, over rough surfaces, it must also be noticed among these inventions ; as must their power of transferring themselves by threads ; while I may here also mention the still somewhat mysterious ascent of certain spiders into the air, by the same contrivance ; since, if it does not properly rank in this mode of motion, it cannot find a place in any other.

The motion of the Snail and of the Scyllæa belongs to this class, if the form and nature of the animals differ : it is a transference of the body somewhat analogous to that of the caterpillars and serpents ; though performed chiefly by the expansion and contraction of a foot, aided by a secretion which both smoothes the path and serves the purpose of adhesion. In the Earth-worm, there is also a power of adhesion, as in the Serpent. The motions of the Limpet and *Haliotis* are analogous to that of the snail, and are effected by changing the form of the

curve which bounds the foot; but the adhesion is produced by the formation of a vacuum; as seems also to be sometimes the practice of that animal. In the Razor-fish, the motion must be ranked with creeping; though the visible effect is burrowing, as the contrivance for it is peculiar; consisting in the protrusion of an organ, or leg, capable of being fixed by expansion, so that the body can be drawn after it. It is the principle for the caterpillar modified; as the action resembles that of a ship warping by its anchor: while the velocity is far greater than could be expected from such a contrivance, since it requires an active spade to overtake the latter animal when alarmed. Many of the shell-fish burrow by means of their foot, as the *Solen* and *Cardium*; and some of the *Echinus* tribe by their spines. The motions of the cockle and the muscle are of the same nature as that of the razor-fish, though the action of the foot resembles that of the snail's. The great rapidity of the burrowing worms, and especially of the marine *Lumbricus*, is also deserving of remark: as is perhaps even more the mode of progression, which consists in swallowing and excluding the sand through which it passes. It bears an analogy to the process of swimming in the *Salpæ*, though the mechanical source of the motion is very different. Thus also do the larvæ, of apparently feeble structure and powers, while often of great size, find no difficulty in penetrating even the hardest ground.

Owing to obvious causes, the act of climbing, in the insects and the larvæ, is little other than that of walking; further than as there are those provisions, in the feet and so forth, which I have already noticed. In the quadrupeds, it is provided for also by peculiar construc-

tions and powers ; as the utility of this mode of motion is apparent, in both the vegetable-eating and the predacious ones which resort to it. In the Rat and Mouse, and in the smaller animals in the Cat tribe, the claws or talons serve this purpose among others, as they do in the Squirrel and more. In the Sloth alone, the construction for this end is exclusive: the animal cannot move, on the ground, much better than the quadruped amphibia. Hence did the ignorance of natural history once affect to pity this animal ; as another kind of philosophy in this science, considered it an error or oversight in creation: it is not proved that we have yet learned to wait in modest patience for what we do not understand. Where the power of jumping was to be combined with that of climbing, under an obvious necessity for both, we find the activity and precision of the Squirrel, emulating that of the Goat, the equal activity, with the four hands of the Monkey tribe, the prehensile tails of some, and apparently, a prehensile nose or trunk in another, with that most remarkable of all these contrivances, the parachute wings of the flying Squirrel and Lizard.

The power of jumping or springing, simply, may, in the quadrupeds, be considered as a modification of running: in the insects and larvæ, it is a distinct mode of motion, and often provided for by separate organs. In the former, accordingly, with but a small exception, there is no peculiar construction for this purpose: everything is performed by mere muscular action, under the impressed instinct, while, in every case, the uses are familiar. In the Cat tribe, springing from the crouching position, we are bound to remark the combination of immense muscular power and of actual strength of arti-

ulation, with that laxity of movement and gait, giving the semblance of feebleness and want of firmness in the joints, which was equally required for the purpose of crouching and insinuation. In the Goat, the Chamois, and more, the activity is equal, and the result is the same; but the object was a very different one, and accordingly, these animals cannot perform what the others do, though the muscles are similarly placed and of equal powers. They must spring from the state of upright rest, as they return to it; while the cat falls into the position whence it sprung: because, to each, its peculiar mode was necessary. The instincts here effect more than the construction; nor can either perform what the other does. The active and similarly constructed Deer and Antelope, bounding like the Goat, cannot imitate it in coming to rest; and the Horse, leaping readily from a run, is with difficulty taught to spring from the former state. It is in the proper springers, such as the Jerboa and the Kangaroo, that we find a specific construction for this end; while here, almost as in the Sloth in the former case, it is not merely the prescribed mode of motion, but almost the limited one: since these animals are unable to run, and their walk is both awkward and imperfect; demanding, in the latter, the aid of the tail, as a fifth leg, in number, but a third in point of use. The springing, or hopping motions of birds, are of too trivial a nature to demand notice.

In the springing insects, the objects are the securing of prey, or simple locomotion, with probably also a purpose of defence; while in some cases there are peculiar constructions for this purpose. The jumping Spider in

the former, seems but the mimic of a tiger: in the Flea and the Grasshoppers, the power is provided for in the enormous hind legs, though in the latter, wings are also used to aid. In the Podura there are legs acting like springs beneath the tail; while the Lepisma possesses eight pairs for the same purpose: as, in the Elater, there is a process on the breast fitted to a socket from which it can be suddenly disengaged, effecting the same end. The Monoculus, though acting in this manner under water, is equally powerful out of it; while far exceeding any of those in muscular force, since its velocity is such, that it seems to be in two places at once. We often think we see two on a large fish, when on securing it we discover there has been but one. Some of the maggot larvæ, as is well known, jump with great activity, by restoring themselves suddenly from a curve to a straight line, thus making themselves into springs; as some of them also possess hooks for uniting the body into a ring, for this end.

In turning to the mode of motion through flying, I shall scarcely be contradicted in saying, that if a mechanician had known no animals but the quadrupeds, he would not have believed that a creature of great weight could have been constructed to fly through the air, and to rest on it with as much security as those walk and rest on the ground; as still less would he have suggested the means. A philosopher at least, accustomed to abstraction, will admit this: whatever difficulty may be found by those who believe their familiar knowledge to be necessary and innate, forgetting how it was acquired. Yet this problem is effected; widely, in respect to the velocities and the varieties of this mode.

of motion, and in a very remarkable manner as regards the weights thus sustained and moved: so unimportant are difficulties, under the resources of the Creator.

The general construction for this purpose, under what is a mere variation from the form of the quadruped, is already understood, in the conversion of the fore extremities into wings, the enlargement of the breast bone, with its powerful muscles, the extent of the lungs, the hollowness of the bones, and the levity, compact arrangement, and strength of the feathers: to which I must add the form of the body and the smoothness of the surface; the first constituting one of those figures which, as in fishes, mathematicians are pleased to term solids of least resistance, though far from having yet mastered that difficult branch of analysis, in either case.

The form, position, and action of the wings constitute the principle of motion: the two first differing little in the several kinds, otherwise than in spread or length, but the latter varying considerably. The motions used in flying are familiar: but it is not so obvious how progression is the consequence of what appears to be a series of vertical alternate impulses on the air. A mathematician should find no difficulty, through his doctrine of the resolution of forces: but they who are not familiar with this science, yet who know that a ship can advance, under many obliquities of the wind on its sails, and who will recollect that the motion of the wing is equivalent to that of the breeze, will form a sufficient conception of this subject, from the following facts, which they may not have analyzed. The impulses are not vertical, but obliquely curved, backwards and forwards, from that line to the horizontal;

while the convexity of the wings, with the comparatively feeble action of the expanding muscles, diminishes the resistance forwards, as their concavity, with the rapid and powerful action downwards and backwards, and especially in the latter direction, gives the impulses for motion. In the different positions of the wing also, it is a sail acted on by a more or less favourable oblique wind; going “large” when in its most favourable position, and “near the wind” when in the least; while, as in the ship, the progressive impulses are aided by the form of the bird, and while those inevitable ones in a vertical direction, which follow from the necessary construction, are checked by the lateral resistance, and further, balanced against each other, so that there is no lee-way. That lee-way, it is plain, would be upwards: and it can be produced for the purpose of ascending, by modifying the action of the wings, as is done by the Lark. All else is simple; and if the bird advances against the wind, it is merely because the motion of the wing is the more rapid of the two: it is a stronger opposed breeze. The tail, as all know, is used for balancing: if it occasionally assists in the steerage, this also is the proper office of the wings.

There are not many variations in this motion, requiring notice for the present purpose: but such as they are, there is an object and a use in all; as slight differences in action and form accomplish every thing. In the sea birds which neither dive nor swim, long flights and great duration were necessary, because their food is often rare and wide apart, and far also from their homes. Hence the great and untiring powers of the Gulls and the Gannet, and of the Albatross above all; the velocity of which is also said to amount to a hundred miles in an

hour. If greater muscular powers have been conferred in these cases, so has a larger wing; while this is one of those unnoticed contrivances for saving exertion, the wisdom of which is apparent as soon as it is stated. The short-winged Sparrow must close the wing to the sides, as must the Partridge, frequently, and with great force, that it may gain sufficient velocity; whence the noisy flight of those birds, while they are also unable to maintain it very long. The sea fowl in question need not labour so hard; the size of their sails is a compensation for that slighter exertion under which they are always "nearer the wind." In the far-migratory birds the arrangements are similar: there is great muscular power, or great spread of wing, or both. If the short-winged small birds sometimes migrate, it is to short distances, as we know that they are also often drowned at sea: but the general rule will be found to hold, as is familiar in the Wagtails, the Lark, requiring long wings, however, chiefly for the sake of its peculiar flight, and others.

There is a remark which I must here interpose respecting the muscular power in birds, that the reader be not misled by the reputed authority of Cuvier, on this question of physiology, any more than in the mechanical analysis of flying, where his confusion and incorrectness are as conspicuous as his solution is defective. If, as he asserts, the peculiar strength of their muscles depended on the quantity of their respiration compared to that of other animals, whence the extraordinary strength of the Serpent, breathing little, and of the Conger eel, as a single example among the fishes, breathing only water? The strength of the closing muscle in an Oyster, and of the adhesive foot in a Limpet, is equalled

by their perseverance, and exceeds anything known in birds. We have no reason, from anatomy or aught less, to believe that more air in proportion is consumed by the insects than the birds, yet their muscular power is a hundred or a thousand times greater. There is the obvious purpose of giving levity, in the quantity of air which the latter include: if they consume more, that consumption is probably necessary to the production of their high temperature, and probably also to the due formation of their blood, under the unusual quantity of food which they consume; as it is this also which enables them, and not less the fishes, to support the great exertions which they make.

If the Swallow demanded long wings and great power, for the same reason as the sea birds, still more were these necessary for the pursuit of its agile and scarcely visible prey; not attainable, had it not possessed the power of suddenly changing the line of its flight: as to this is added the highest known velocity in birds, since the motion of the Swift has been computed at seventy feet in a second. In many other birds, where similar angularity and rapidity of movements were required for the same or analogous purposes, there are appropriate arrangements, in the actions, or in the wings themselves: while all those especially which pursue a small and active prey, display that universal agility of movement which confers so pleasing a character of liveliness on this most cheerful part of creation. The Wagtail, pursuing on the ground what the swallow does in the air, seems incapable of keeping itself at rest: ever in motion, because motion is not so easily commenced from a state of inaction: and thence probably the length of its apparent superfluity of tail. In the Falcon tribe, I

need not repeat what I said of the sea birds ; but that peculiarity of motion necessary for watching the movements of their prey on the ground, is, in them, a distinguishing feature. Nor is the power of hovering so mysterious as it often appears. The bird, in this case, is a light parachute, of considerable extent ; only requiring that its balance be preserved by a slight exertion of the tail and the point of a wing, easily moved or restored to its place by a very slight impulse, and opposing no surface to the wind, which the bird cannot easily counteract. In the fluttering repose, the wings are caused to act vertically alone ; and thus a fixed position is as easily maintained. In the Humming-bird, there is the same power, for a well-known purpose.

The Bat must also be classed here ; since this is nearly the only mode of motion it possesses, although a quadruped, or a mammiferous animal. The peculiarity of this exception, or anomaly, I have noticed elsewhere ; and need only now remark, that pursuing the same prey as the Swallow, it exceeds it in quickness of angular motion, though under so different a construction, although it is possessed of little velocity. And I may here notice that contrivance, equally simple and effectual, through which these animals are enabled to avoid obstacles, even in utter darkness, and without which they would have been inefficient for their appointed mode of life. This consists in the high sensibility of the skin of the wings : and had naturalists ever observed that the blind man, and even he who ceases to see in twilight, possess the same power through the sensibility of the face, and indeed of the body in general, as does the Medusa, following the light when confined in a glass, they would have found no mystery in this

fact, and might also have dispensed with their cruel experiments. To the Vampire, a motion like that of the humming-bird and the falcon has been given, for another purpose.

Here also I must place the flying fishes : while if the use of their peculiar structure is not very apparent, since the power of escape is scarcely a sufficient one to account for such an anomaly, we may at least admire the resource and power, which, in both these unexpected cases, has effected what natural history has, by implication at least, assumed as impracticable, in determining that the peculiar construction of a bird was necessary to the power of flight.

In the insects, we do not find those anatomical differences between the walking and the flying ones which are so striking in the case of the quadrupeds and the birds ; while indeed there are some, like the Ant and the Aphis, which walk and fly at different periods of their lives, gaining wings, and again losing them. Nor has any attention been here paid to non-resisting forms, as in the birds ; as the head, on the contrary, is often the largest part of the animal. It is probable, that under so small an opposing surface, the great muscular powers formed an ample compensation. It is familiar that the numbers and sizes of the wings differ very much ; but we do not always find that much is gained by numbers or extent : muscular power renders the bee an infinitely more rapid animal than the butterfly. The constructions of all these wings are well known ; their forms seem to be planes, in action as well as at rest, their motions appear simple, and yet we do not know how they act in producing progression. Naturalists seem to have forgotten this, in speaking of

their vibrations; forgetting that something more is necessary. A mathematician can at least see that the question is not solved; if he is unable to give the solution, for want of knowing what the motions really are.

The rapidity of muscular action and alternation in these cases must not be overlooked: it is more extraordinary than in those of the running insects I formerly noticed; being indeed such as to appear incredible, when we recollect that two muscles must be alternately put into action and relaxed, at each vibration. Fortunately also we can here measure this rapidity, wherever at least the wings are audible, under the law for musical vibrations, so that on this point any one can satisfy himself; while as the note appears very constant in each insect, we equally perceive that there must be a great precision in those motions. If the Gnat sings louder in the ear as it approaches, it is but the upper octave becoming audible by approximation, as it does in the tuning-fork.

The strength and endurance are far more extraordinary here than in birds. Many seem to pass their whole lives on the wing; and if the times and the velocities were added together, the spaces traversed would sometimes appear incredible, for animals so small. That many also migrate very widely, is known in more cases than that of the Locust. If I have noted the rapidity of the Swallow, that is far exceeded in the Dragon-fly, since the movements cannot be followed by the eye: while, to rapid angularity of motion, this active animal adds the power of flying backwards or forwards with equal ease, and of changing those directions instantaneously. I need lastly only note the hovering motions allotted to those which feed on

honey ; more than rivals, in this, of the humming-birds, and for the same purposes. Every one knows, it is to be presumed, that the wing-cases do not assist in the act of flying.

The several modes of motion which rank under swimming, though assigned principally to the sub-aquatic animals, are not rigidly confined to those. Every land animal nearly, till we descend to the different tribes of worms and terrestrial Mollusca, is empowered to swim, in some manner ; as, in the quadrupeds, the birds, and the reptiles, there are many destined to an united terrestrial and aquatic life, or to one which is even more aquatic than terrestrial.

In the quadrupeds in general, it is an occasional mode of motion for change of place, as for security against accidents ; while not many attempt it, without urgent cause, such as escape from danger, or hunger. It is indeed said that the Fox, in the northern regions, fishes in this manner, as the Dog has been taught to do. As to the mode of action in all these cases, it differs little from that of walking, the buoyancy of the body effecting the rest ; though where this happens to be great, as in the Deer and the Ox, the facility is much increased. In the Elephant, it would not be possible but for the trunk, which enables the animal to breathe, though deeply immersed. In the amphibious mammalia, being not always quadrupeds, there are sometimes peculiar constructions for this end, if the broad paws of the polar Bear suffice for its purposes. All the marine divers have fins to replace the hinder legs ; the mode of life in those approximating most nearly to that of a fish ; as at the lowest point in this division, I have formerly marked the gradation from the Manati

to the Whales, in the acquisition of the tail of a fish, and the disappearance of the hinder extremities.

The swimming birds display a graduated series of powers and desires, not very different from those which lie between the Otter and the Seals; but no terrestrial one takes the water from choice, or under any urgency, though all floating with the utmost facility: it was unnecessary under their ample powers of locomotion. Among even the birds which feed from the sea, the Terns and the Sea-eagle do not touch it, otherwise than with their bills. The Gannets plunge into it, like stones, without swimming or diving: and the Gulls swim, but do not dive, being provided with paddles for that purpose. The stormy Petrel lives for ever on the waves, without diving, taking to the shore only to breed; though the far greater number of the swimmers and divers sleep on the land. In all of these alike, the provisions for these motions are made in the paddle feet, and in the peculiar position and action of the hind legs, which are extreme in the Cormorant and the Penguins; while in the latter the wing is reduced to little more than a fin. Lastly, in the longer-winged divers, the submarine swimming is effected chiefly by means of the feet; as in those of short wings the action resembles that of flying, since the wings also are used as paddles.

In the amphibious reptiles, the swimming machinery and the modes of motion, in the Frog, the Lizards, and the Tortoises, are familiar, and require no particular remark: it is but the same principle of progression which is applied in the Seals. But in the Serpents, the action is that of the fishes which have no pectoral fins, which I shall have occasion to explain immediately. The great provision however, deserving notice, in all these cases,

is that which is made in the lungs. They can comparatively dispense with air; though the cause does not well appear in the warm-blooded animals, if we can more easily admit this repose of the lungs in the tortoise and the frog. It is however needful to recollect that the tadpole is truly a fish, if a temporary one, unable to exist on the land: possessing gills, which disappear under its change, by the obliteration of their arteries, when the previously dormant lungs come into use. There is the same double provision also for the land-crab.

There is no other place than this, where I could have ranked a few animals which, belonging truly to the sea, as fishes, can live on the land, and also seek it: being thus amphibious, in the literal sense, though not to be ranked with those already named. But two, however, are I believe yet known. One is the *Antennarius* or *Chironectes* of New Holland, which walks on the land, voluntarily quitting the sea, by means of its ventral and pectoral fins, as it can also remain there many days; and the other is the *Anabas*, or *Perca scandens* of the eastern ocean, which quits the sea to climb the trees on its margin. That the Eel has a similar power, is well known; while its motion on shore, as also that of the sand-eel, does not differ from that in the water, resembling the flat progression of the serpents. In none of these cases of gills, including that of the Crabs, is it well known, as I formerly remarked, whether they can breathe air for a time, or dispense with all respiration. In the case of the two fishes just named, the former is much more probable.

Of the water insects, I had occasion to speak formerly, scarcely knowing how to rank them. I may here add another which is a true diver: a kind of Spider which

surrounds itself with a web capable of retaining air, and thus descends beneath the water, in a diving-bell of its own construction. But no merely flying insect swims; this tribe not being able even to float very long, from the entrance of the water into their tracheæ; nor do I know of any terrestrial one that takes to it or can exist in it. The larvæ which are aquatic must, for the present purpose, rank with the properly aquatic inferior animals.

Our own ingenuity has hitherto discovered but few modes of propelling bodies through water, by making the water itself the resisting force. Of these, the oar and the revolving chain of paddles, being but one in principle, are alone of any value; as the revolution of a spiral, to which the scull may be associated, and the recoil of water through tubes, form the others, though the latter exists but in theory. And these last are the only inventions in which the machinery is submerged: we have not hitherto been able to construct an effective paddle which shall not be lifted out of the water, though Nature's models are before us in many forms. Yet it is not for want of interest or thought; while, without this, the steam-vessel will scarcely become an expedient machine for warfare. Yet the Creator has effected this in many different ways, through wisdom which we might borrow, but with power that we cannot imitate; as also under a variety of invention and resource, which seems to have no other object but the display of those powers.

The most prevailing of these inventions is that which is applied to the fishes, and under very slender variations. How powerful and efficacious it is, I need not say: the velocity of many fishes is like that of lightning; and taking a broad view of the whole in the two

tribes, it infinitely exceeds that of the birds. The medium indeed offers a much stronger resisting point for the impulses; but that is compensated in some measure by the greater anterior resistance. The general construction I need not describe; and I formerly showed that the air-bladder, present, with perhaps a few exceptions, rendered unnecessary all exertions for support in this liquid atmosphere. That the form of the body, generally, is that of a little, or a least resisting solid, it is also sufficient to recall to the reader's mind.

The nature and action of the moving forces will be easily understood from the following explanation, though misrepresented in the most recent works on natural history: and I should not do justice to the reader did I not say that the swimming of fishes has been as completely misapprehended and mis-stated by Cuvier as the flying of birds: since authority such as his has been esteemed must always mislead those who are incapable of examining for themselves. How his confused and unintelligible descriptions should have been received by naturalists and escaped the censure of mathematicians, it is for them to explain. The action of a fish admits of a much simpler mathematical analysis than that which constitutes the flight of a bird. The longitudinal fins, both above and below, serve only to preserve the vertical position and balance. The ventral, or podal fins, not always present, appear to assist in this office; as they also serve to change the position, both horizontally and vertically, as they produce small motions, and regulate motions in a direct line, and perhaps also aid the main action of the pectoral fins. In slight motions, these latter act as mere paddles, or are

real instruments of progression; while they are also used when the fish is at rest, to aid the circulation of water round the mouth, for the sake of respiration; in which case they are kept in a quick tremulous motion. This view of the subject is confirmed by the paddles near the gills in some Crustacea, which are always in motion to produce currents of water near them. Probably also the cilia in Infusoria and others serve for this purpose, as well as to bring food along the current of water. But so far from being the instruments of quick progression, as has been represented, the pectoral fins form a retarding force, and this is their main office. The impelling power is in the tail, or caudal fin; and it often depends more on the muscular force of this organ, than on the breadth of the fin, what the velocity shall be; as it is visible in the Mackerel compared to the Gurnard. The mode of action is easily comprehended, without regard to the resolution of forces; though a mathematician will see how this law modifies the power, in different positions of the tail. When it is brought forward in that alternating movement which constitutes swimming, the effect would be to pull the body backward; to prevent which, it is contracted, and the pectoral fins are extended, so that the animal becomes fixed: while in returning the tail to the straight line, it is expanded, and the pectoral fins are closed; when the act of propulsion takes place. In this last position, the direct force becomes nothing; but the alternately lateral ones are neutralized by the breadth of the body and of the dorsal and anal fins; just as the leeway of a ship is checked, by the water acting on its side, and the pressure of its sails to leeward. The anal fin serves for steerage as well

as for balancing the body, by means of a lateral motion.

Where the tail is horizontal, there is no essential difference in the mode of motion; and I formerly showed the use of this, in the flat fishes, and in those which breathe air. When there are no pectoral fins, the restraining force is obtained in another manner. In the Tadpole, and the Vibrios of similar shape, the bluntness of the head, added sometimes to a flexure of the anterior part of the body, becomes effectual for this purpose; and the mode in which this acts is obvious. But in the perfectly cylindrical swimmers, which have no pectoral or podal fins, including the long Vibrios, the Serpent, and a few among the fishes, the detention is produced by bending the forepart of the body at a right, or considerable, angle to the line of direction while the tail is brought forward, and straightening it as that returns to its place. Hence that alternate undulation which is seen in these fishes under motion; while the Eel makes use of the same means, although possessed of the pectoral fins. These indeed do not seem to be here used for this purpose; while in one species, the *Muraena serpens*, they are so small as to be scarcely visible, being wanting in some others, as they are in *Synbranchus* and some species of *Sphagebranchus*. I think we should be safe in believing, that if a mechanic had invented the pectoral fin, he would have been at a stand if deprived of it: this substitution affords another example of the inexhaustible resources of Creation.

The simpler principle of the paddle has been adopted for a great many among the inferior marine tribes, and under numerous variations. The Lobster and its congeners are the most familiar; and the machinery, with its

action, is here so obvious, that I need not describe it, further than to note the mechanism for closing and expanding the tail fin, and again to point out the resource which has avoided repeating the contrivance adopted for the swimming birds, though here equally applicable. Such is the velocity produced by this machinery, that a single flap of the tail will carry the animal through a space of thirty feet, and with unerring precision, into a narrow orifice. In addition however to this principal mode of motion, many of this tribe have a provision for swimming forwards, by means of lateral fins, acting as paddles; while all can do this by means of their numerous legs. The former are the motions for escape; the latter for the ordinary purposes of these animals.

In a very large body of species beneath these, arranged, or rather confounded, under the term *Cyclops*, the paddle is applied in another manner; but while these, like the former, may be termed submarine jumpers, the motion is forward, instead of backward. In this case, extending widely through species very different from the preceding, of which also many are microscopic, the paddles are folded under the body, when at rest, so as open backwards. The spring of the animal is therefore forwards, and is so rapid that it cannot be observed: it disappears at one spot, and we see it in another; while the distance very far exceeds that in the *Lobster*, comparing the sizes of the animals. In all these, I may also add, there is a separate and slower motion of swimming, performed, probably, as in the *Shrimps*, by means of the legs; as the enormous antennæ, often more than ten times the length of the body, seem to assist in this, as they plainly do in shifting the positions: being an application of that organ which seems to have been un-

noticed. If I have already mentioned the similar motions of the Monoculi, under the action of a tail, the rapidity is such that I never could discover whether the animal went backward or forward, or what the action really is.

I need not describe any other variations of these springing paddles : and it is sufficient merely to note, that in the many-footed marine insects, such as the Nereis, the feet are used for fins, as those of the shrimps are ; though they also swim by means of the undulatory motion. In the Beroes, the paddle is applied and used in a very different manner, and for slow motions : a great number being set round the oval body, in rows parallel to the axis of motion ; while the effect produced is as trifling as this machinery is operose.

I may pass to a very different principle of motion, adopted for the Medusæ and the bivalve shell-fishes ; different as these constructions are. The simple Medusa, without tentacula or other corresponding appendages, resembles a tea-cup or a saucer. To produce a forward movement, the margin is suddenly contracted or closed, and the effect follows. It is the principle of the bird's wing, under a somewhat remote modification, applied to water instead of air. In the shell-fishes in question, the open shell is closed in the same manner ; while the resemblance to the wing is here more near. Thus can the Oyster move sufficiently ; as the Pectines do with considerable rapidity. That the univalves can also swim, if swimming it can be called, in some manner, is known ; but as far as I know the method has not been discovered, while the opportunity has not occurred to myself.

To swim by means of tentacula, is yet another in-

vention, or rather seems to comprise two distinct principles of motion; though in all the cases it is not easy to discover which it is that is adopted. In the tentaculated *Medusæ*, these organs, often very numerous and long, are thrown alternately forwards and backwards with a jerk, in the line of the animal's progression; but this division is so small in size, for the most part, that it is difficult always to discover what the proceeding is, though the velocity is far greater than that of the simpler *Medusa*. In some cases nevertheless it is plain that they act by repulsion: in others, as evidently, they are thrown out as a kind of floating sets of anchors, and the body is dragged up to them; as this also seems to be the principle of motion in the *Cuttle-fish*.

The recoil of water is another of the principles which has been here applied; being one of those, as I already remarked, which we have proposed to adopt. It is used in the extensive tribe of *Salpa*, and in *Dagysa*; in which a tube containing the gills passes through the whole length of the body, furnished with a valve at one extremity, so that the action of breathing is likewise the swimming power: as appears to be the case also in the *Medusa*, though under a very different arrangement. The larva of the *Dragon-fly* performs its movements in a similar manner. In the operose and beautiful animal resembling a *Beroë*, which I described in the chapter on mechanisms, it is similarly the recoil of the water ejected by these chain-pumps, which produces the motion; while these also probably act the part of gills, in addition. It is a combination of the structure of the *Salpa* with that of the *Beroë*; yet the effect produced by all this contrivance and mechanism is extremely small, since this is one of the slowest of the

animals among its associated tribes, as I had formerly occasion to notice.

If these principles and constructions are generic, they do not comprise all the remarkable variations under the latter ; nor do all the principles which have been adopted seem to be exhausted, though I am unable to discover what those are, in some cases which I know not how to reduce under any of the preceding heads. This subject has been entirely neglected, by naturalists and mathematicians equally, my opportunities with these animals of difficult access have been very limited, and they are often individually rare, obscure, and of microscopical minuteness ; while they must always be examined under their rapid motions, in large masses of water, where only a transient sight can ever be obtained. Nevertheless I shall note the remainder, since the variety of resource and power is here the object in view ; as it will be seen that some of them, at least, can be reduced or approximated to one or other of the preceding principles.

In a microscopic genus with more than one species, the shape is that of an ale-glass without its foot, when at rest ; and the motion is produced by expanding the extremity, till the figure of the perfect glass is assumed ; protruding it at the same time against the water. In the larva of *Ditiscus*, the same principle is applied ; but the instrument is a fringe of hairs. It has been proposed to adopt this machinery for boats ; but hitherto it cannot be executed. In the *Vorticellæ*, where the anterior part is surrounded with a fringe of tentacula resembling hairs, there is sometimes a tail ; in which case the motion is that of the tadpole vibrios : but the movements are also extremely rapid, far more so indeed, where there

is no tail; and unless these are produced by the tentacula, as in the minute Medusæ, I do not know the source of motion.

The term *Trichoda* has been applied to many minute animals, though very different in appearance, having a globular or ellipsoidal body, with two fringed wings at one extremity. In others, there are wings of various shapes and sizes, and in different positions, resembling the membranous wings of insects; while the motions of all these resemble the flights of those animals in the air. In another genus, of many species, large enough to be easily distinguished, the whole form, wings and all, resembles a Wasp; and, when in action, the latter are brought from their state of rest at the sides of the animal, and used just as the wings of this insect are, so that it appears to fly in the water. It is discernible that they are constructed like the fins of fishes; and we must therefore consider all these as modifications of the swimming paddle. The movements of the *Clio* are performed in the same manner. That principle under which the *Medusa* and the bivalves act, is applied in this minute department also, under a new modification: I have found it in three species, under two new genera; the one bearing an absurd resemblance to a man, and the others being spindle-shaped bodies, bifurcated behind. The semblance of the arms, in the first case, and the bifurcations in the other, propel the animal by closing. The former approaches most nearly, of all that I have yet noted, to the wing of a bird in action: as, in place, it is identical.

By degrees, the difficulties of explanation become greater; as, at length, the solution is for the present hopeless. The spherical *Trichoda*, demanding a very

different genus, swims, probably, through the tentacula which cover its whole surface. The *Daphnia*, having these at one extremity, probably also does the same. In *Nauplia*, and other unnamed ones of analogous construction, the singular claws seem to be used as fins ; but there is one of those still undescribed, the sources of motion in which cannot be conjectured ; the appearance, when moving, being that of a sphere revolving in all directions, with a rapidity and violence which are quite startling ; since, under the microscope, this ferocious animal appears to be almost in contact with the eye.

There is one very comprehensive mode of motion, including a great number of animals, which have no appendages, and are ill distinguished and worse named : abounding, under many forms, in the sea, as they are also the most common ones in the vegetable infusions. They are all simple solids, of some form, and that form is changed to another when they move ; as this is the apparent cause of the motion. If the principle of motion is not often very intelligible, it differs at least from all that have preceded, while it evinces peculiar resource ; since to move a body in a fluid, without the aid of any attached mechanism, is a problem that would be in vain proposed to ourselves. But those simple constructions were intended ; and the difficulty which had been produced is, as usual, overcome. In the *Leucopha*, under many more species than have been noted, the body at rest is a sphere ; and, in the act of motion, this protrudes triangular points, so as entirely to change the figure ; the varieties being, one at each pole of the axis of motion, or one only, behind, or one at each side, at right angles to the progress, or three, of which one is

before, or five, of which two are behind. How the posterior protrusions should cause the motion, is obvious: the rest is unintelligible. A more common change is that from a sphere to an ellipsoid, or a spheroid, or a spindle, or to a curved ellipsoidal solid of some shape, but under many more forms than can or need be described; and these are sometimes the causes of considerably rapid motions. In some of them, we can approximate at least to the cause of the motion: in others, where we may imagine that, it will not bear the test of analysis; since, although there are motions, they prove to be balancing forces, which ought to leave the body in the same place, though not at rest. There is probably something which escapes us in those minute objects.

There is yet one more class of motions producing progression, where the difficulty is the same; we cannot conjecture where the propulsive power lies: while if some of these animals possess tentacula, or tails, we can ascertain that those at least do not move. The body, whether provided with such appendages or not, is a flat spheroid, or a flattened ellipsoid; and if the hand be turned, with the palm and the edge alternately foremost, it will represent the motions in question; while the progression is in the plane, in one way apparently. It is here possible, however, that there is some motion imperceptible to us, under which the whole animal becomes a sort of paddle to its own body. In any view, it is another invention, and where, for aught that we can see, the former might have been applied, as the appendages might also have been used for the purpose to which they are so often dedicated. Among those which move in this manner, the *Tripod* resembles the Greek

capital Upsilon, with the body at the junction of the branches; but there are many species besides that one, which alone has been noted. Another, undescribed, of which also there are more than one species, is like the hieroglyphic assigned to the constellation Taurus.

Lastly, all possible conjecture fails. The animals make progress through the water, without appendages, or, if with them, no care, however repeated or prolonged, can detect the slightest motion of a part, or change of form. Among those, one resembles the spindle used in spinning, another, the double-headed shot, and a third, a sphere, with a cylinder projecting from two opposed points on it; as I have also found four species, in a genus which resembles the worm-screw of a ramrod, and twelve, termed *Vibrios*, like so many more, which are straight and unbending hairs in shape. Some conception can indeed be formed of the progression of a spiral, without a visible action; but the others are, for the present, hopeless.

One general conclusion cannot fail to strike the reader. The lower down we proceed in the scale of forms, the greater does the variety appear; and we now see that it is the same as the motions and contrivances for motion are concerned. There is but one general scheme for that of the fishes, and but one for each division of flight, in the birds, and in the insects. The twenty-fifth chapter would scarcely have been complete without the present one, independently of that display of hydraulic knowledge and resource which has here been exhibited. But this cannot be all; nor is it. I know there is more; I do not doubt that there is much more than I have seen. Naturalists with better opportunities will find it, and future mathe-

maticians will solve what I cannot. But of all these numerous and strange notions, I must remark what concerns the former, as it also does the views under which this chapter, and all else, were written. Everywhere, though the forms and the modes of motions are similar, we recognise each species by its peculiar gait, if I may use such a term; so positively is it defined how every animal shall act. We need not see a horse or a deer, a pigeon or a partridge: it is sufficient that we even hear the trot or gallop of the former, and the flight of the latter, to recognise the animals. Thus it is in this minute and multifarious department. Every one is known by its peculiar motion; and thus can we also distinguish the kinds, or perceive that we have discovered new ones, when the forms are not strongly marked, or when they might have escaped our notice.

I have found no place hitherto for the Argonauta, the Nautilus of poetry. It is the anomaly which ranks with nothing, as its sails at least are concerned. Its wide fraternity in the floating shells, work their ships by paddles. From the former man might have borrowed the sail, as he certainly did not: I doubt if he will succeed in imitating anything which has here passed in review; for it is machinery which he cannot execute, and power which he cannot communicate.

CHAPTER XXIX.

ON THE ORGANIZED STRUCTURES; IN ANIMALS
AND PLANTS.

THE very term, Power, is so commonly associated with effort, or with magnitude, extent, and other ideas connected with vastness, that it requires a certain exertion of mind to view it as operating in minute objects : and hence has this attribute of the Deity been sought in the great bodies and phenomena of the universe. Yet the contemplation of those alone will convey but very limited notions of the power which has been exerted in creation ; since, notwithstanding its vastness, the great system of orbs is perhaps the simplest of all the works of the Deity. To Him, mere magnitude is nothing : and therefore we may view those myriads of globes as so many grains of sand, separated by such distances as to admit the whole visible heavens within the space of an ordinary apartment. And we see almost nothing else : nothing, as it relates to Him, and but little, compared to the whole display of His power. A single effort of will put all these globes into place and motion, and another command maintains their order for ever.

I do not, however, undervalue this great act of power, which will come under review hereafter. My only wish is to prevent the reader from dwelling on this demonstration so exclusively as he has been taught to do ; to remind him of the numerous other modes in which the

Creator's power has been displayed, and to induce him to reflect on the multitude of things created and actions maintained through exertions of power far more complicated, and laws more obscure, than those which maintain, the great system of the universe. And as the present purpose is to display examples of that power in some of the minutest works of creation, I am desirous that he should at once lower the tone of his feelings, and of his expectations, as excited by the term, Divine Power, so that he may justly view and appreciate what will be here presented to him.

If magnitude be nothing as compared to the Creator, so, it has been said, is minuteness. This indeed is true, metaphysically speaking; since the question of difficulty can never apply to Him. But we must always judge by our own experience, and by a reference to our own powers; without which, nothing in nature could excite our admiration or awe. All would be alike, and all would be equally without interest: His wonders in the air or the ocean, the rarer and the grander phenomena of nature, would produce no more effect on our minds than the most trivial and common; and not even a miracle could excite us, when we reflected that to Him a miracle is nothing. It is but by imputing difficulty that we conceive power. We know this to be false in reason: but while the feeling is unavoidable, so is it necessary for the present purpose. "God is not a man," we know: yet such is the constitution of our minds, that thus do we judge of His works, if unconsciously; correcting ourselves only by reflection. And if it is thus also that we admire, estimate, or wonder, making ourselves the standard of comparison, so have all His attributes been

thus judged in this work, as they ever must be ; while it is even thus too that Scripture itself speaks of Him.

In the cases about to come before us, we nevertheless perceive real physical difficulties, depending on His own appointment. He has created certain kinds of matter, possessing properties which we familiarly know, and see to be limited ; yet He executes with them purposes to which they seem utterly inadequate. This is the difficulty, created and overcome : it is as if He were contesting with Himself ; and thus is it a special demonstration of power, if we admit that there are any such demonstrations existing. The philosophical truth indeed is, that we were not thoroughly acquainted with those properties, and had unduly limited them : since even He does not work contradictions. But if we wonder because we cannot discover the means by which He effects His purposes, we must estimate and admire when these become known to us. In either case, to the ignorant and the informed, the results are efforts of power. The former must feel this as soon as the facts are pointed out : and the latter cannot avoid it, under all his knowledge and reasonings, because he cannot, though he would, forbear the comparison of the power of the Deity with his own.

I formerly gave a general sketch of the animal and vegetable structures ; but, under the present purpose, I must examine those subjects more minutely. They display power, inasmuch as the materials seem inadequate to the ends effected, and because we can form no conception of the mode, the action, or the “law,” by which these structures are generated, by which they are arranged, and, at the same time, exclusively and steadily

determined. From perpetual familiarity, we forget to note this: yet without the conviction of experience, we should have pronounced the actual results impossible. They are not miracles, in the strict sense of that term, because they are within the order of nature: but under a very common acceptance of that word, they are miraculous efforts of Divine power; and often, not less such than many of those facts which testimony has not yet persuaded all men to believe.

Taking first the simplest view, or the mere act of growth from a germ, an imaginary case will possibly render the desired impression more striking. It is easy to conceive that such a building as St. Paul's Cathedral should grow up out of the ground, because the tales of our infancy call on us to admit this, and more, every day. Let us see what the process ought to be, if conformable to what occurs in organized bodies. If the foundation stone may represent the seed of the tree, it would produce successive courses of stone, according to the architect's design, till the body of the structure was completed; and the columns, porticoes, windows, and ornaments would take their appropriate places and forms in the same manner. The plastering would be deposited, or secreted, on the surface; the cupola, in all its framework and covering, would then be produced, and, finally, the whole would shoot out the gilded ball and cross. Yet, still further, that ball might be removed to another spot, where it would grow up into a similar cathedral.

Vision as this may seem, it is what happens before our eyes every day: but the cathedral would be a miracle; the tree is none. Yet surely the Power which daily constructs the latter, might equally have made the former: and had He done so annually, it would not then

be a miracle, though no custom should prevent us from viewing it as a great, or a miraculous effort of power. But the growth of the tree from the seed, or of the animal from the egg, is as great an effort, or wonder, as that of St. Paul's from a stone would be ; being a work wrought from materials and built without hands. In the former cases indeed, the forms, or particles, the equivalents of the stones, are invisible, as is the mode of their application ; but we know that there are such forms of solid matter, and that they are applied in succession, according to the Architect's design : while the parts which they produce are far more numerous in quality and shape than aught that building can show, as the total structures are far more incredible.

But an answer is ever ready. The animal and the tree are organized bodies : their growth is the consequence of organization and life, their forms are determined by a law for each. This is an answer that solves nothing : it consists of empty words. It would even be confessed as such, if we had never seen a tree and never seen a building ; if, for the first time, we could see a tree grow from the seed and produce its various parts. But what if the tree and its materials could be magnified, or our sense of sight rendered such that we could see what we must now infer : see all these solid parts successively applying themselves in due order, till the full structure of an Oak was completed, with all its interior architecture displayed ? We should at least conclude that some hand was executing this work, though it was, in some manner, invisible : even as we conclude that hands built the cathedral, though we did not see them employed on it. And if these very different productions should grow for the first time in the same

manner, it is certain that the tree would be considered a far greater effort of power than the building. But if we actually saw a being, a mechanic, applying atom to atom till he had built up a tree in all its anatomy and parts, producing also wood, leaves, flowers, honey, colour, from the clay that formed his foundation, and, at the same time, saw another erecting a building, even with one, instead of various and prepared materials, we should certainly award the palm of power to the former.

Yet this artist is God. Must we see Him at work before we will believe? Our reason proves to us what our eyesight cannot, in far more than this. He does not indeed work with hands, like man; but He does work, or the structure could not have existed, and He works with power, or it could not have been what it is: with power incomprehensible, for the produce passes our understanding. Did He make but one tree, and did we see Him make it, we should admit His action and His power:—because He works by a word, and not by hands, are we to doubt or deny? It is because He makes millions for ever that we will not believe: even working as He does now, we should believe, had He made but one tree; because it would be that which no one else could do,—because it would be a miracle. This is bad reasoning: but there is no reasoning exerted on the subject. What ignorance knows not, and familiarity forgets, that which is termed philosophy calls a “law:” deserving double censure, while claiming a proud superiority over the former, because it has possessed itself of a word unknown to them.

Commencing with the animal structure, I may begin from the egg: but I must refer to the 56th chapter

for a fuller answer to the question of involved germs than I need give here. We can see nothing in the egg, of what is to be : and though we supposed that every part of the organization, even to the difference of materials, was contained in the white spot, it would explain nothing. Those supposed parts must at least enlarge : while the hypothesis of involved germs must also explain the infinitely greater difficulty of successive reproduction through eggs ; as it is foiled even by the much more simple one of the renewal of feathers.

There is a white spot : we know no more. If the egg be heated for a certain time, a blood-vessel appears, then a ring of pearly bones where the ciliary circle of the eye is to be, and, successively, more vessels, eyes, a heart, limbs, feathers, a living and complete, if not a full-grown animal. It quits the shell, continues to grow, and produces eggs, reproducing more animals of the same kind. This is a machine, and a very complex one : it is machinery rather than architecture ; but it is built up on an invisible foundation, through the approximation of atoms. It is as if heat were to be applied to filings of metal, and they were, within twenty-one days, to arrange themselves into a watch, even to the dial-plate and the glass. In reality, the latter machine is not one-millionth part so intricate, though we should omit the qualities of life, sensation, reproduction, and much more. And if I have just said that the wonder of this process is not diminished by the supposition of a pre-existent form, I may illustrate this by the comparison already used. Should a model grow up into a house, through some internal power, we should not consider the miracle less than if a single stone had produced the same result.

Any one may see an example of this proceeding in the membrane which envelopes the chick in the egg, performing the temporary office of lungs to the imprisoned animal. Before sitting, it does not exhibit the trace of a vessel: at the end of the process, it is one of the most beautiful machines that can be conceived, being an entire double ramification of blood-vessels: as it is also the object which will best convey to a general reader a conception of the vascular structure of animals, and of its mode of growth. But it must be examined as a mechanic would do, if we would form a correct idea of the power, and, I may add, of the thought exerted; since it is a work of labour, even to its slowness. No work performs itself; and if it is the produce of an original law, who are the agents that execute it, or how did they even know that law, promulgated long before they existed?

If now we take the single vessel which first appears in the chick, it becomes elongated as well as enlarged, by successive additions: it then produces a branch, more branches, ramifications still more minute, till these arrive at the ultimate necessary size, when they unite with a similar train, gradually enlarging, but diminishing in numbers, until the last trunk ends in the heart, as the first commenced from it. This is the one arterial and venous system: and it was formerly shown that there are two such. All has been thus gradually built up, with the most remarkable accuracy: while the tube itself is a very peculiar structure, containing an interior polished coat, a second one, of muscular fibres, and a third, resembling the first, but less compact, besides the valves, adding much to the mechanism, and therefore to the labour, or difficulty. We are so accustomed to

see plants branching and elongating, the growth of a straw is so familiar, and appears so easy or necessary, that if we ever think, it is of such a prolongation as might be produced by a wire-drawing engine ; thus equally, not thinking, but forgetting to think, of the growth of blood-vessels. But the valves of a vein, at least, are as independent of such an imaginary process as that of a pump is of its tube : it required a distinct effort of labour, as well as of thought, to produce those. In the lymphatic system, forming a separate arrangement of vessels branching from a common trunk, there are thousands of such valves, often of invisible dimensions, yet all perfect for their work. All this intricacy of tubular structure and ramification is also going on at the same time : all being formed out of a single, fluid material, commencing in nothing, completed together, and no one thing being misplaced, or interfering with another.

This is machinery, even thus far, which leaves all human art at an immeasurable distance : and yet it is but a small part of that whole in which I must still omit much, for want of space for inquiries so extensive. The equally ramified system of the nerves has been built up at the same time, and under more than merely mechanical difficulty ; since, of that mysterious structure we cannot form the slightest conception. Thus also is the bony framework going on : and if we take but two bones with an intermediate joint, we may acquire some idea of the method of working. At first, there is not even an indication where limb or bone is to be : and if we take the thigh and leg bones for example, when first discernible, they are a gristle, or something similar. But earthy matter appears in them by

degrees: and when the mechanism is complete, we find them nicely fitted together by a beautiful hinge, of a different material, highly polished, enclosed in a collar, and lubricated by a gland. Here, there is no prolongation, or extension, or expansion, or whatever is the word by which we try to get rid of difficulties under the term "law." It is even a more difficult case than that of the valves; and, to understand it, we must inquire how a human mechanic would have executed the same work. I need not say that he would have first finished each bone separately, then placed the proper material on the joint and rendered the whole true, next introduced the oil gland, and finally invested the whole with the retaining collar. The great Artist has proceeded in a very different manner. All the parts have been gradually formed at the same time: so that, when all was finished, everything should find itself fitted in its place. I need not prolong the same remarks to the remainder of the skeleton, nor extend them to the muscles and the viscera, or such other portions of the anatomy as I do not name: since the same analysis applies to the whole, and under the same reasoning. Every independent part is forming at once, we know not how, and at length the perfected animal issues from its prison, complete.

He who can reflect on the structure of the animal, as even thus indicated rather than described, will not doubt that it was the produce of power: but the anatomist who really knows what that structure is in all the complication of its detail and minuteness, and will then contemplate the white spot in the egg whence it all arose, must have forgotten to reason, or be at least very thoughtless, if he does not look on it as one of the most

striking instances of the Creator's power which the universe produces.

But what are this great Artist's tools and materials ? A mechanic can imitate an eye as he would a joint : but I need not suggest how he would set about a structure so nice, and consisting of so many parts, so different in quality. The Artist who made it used but one tool, the mouth of a small artery, and one material, blood. By such limited means, was produced a globular and firm case, containing a nervous and painted curtain, on the fore part of which is a circular and convex glazed window. Within, a beautiful transparent lens, the texture of which is incomprehensible, from its intricacy and apparent difficulty, is suspended in its exact place by peculiar membranes, and between two different bodies, one of which is a mere fluid, and the other a gelatinous one entangled in a cellular membrane so fine and transparent as to be undiscernible ; while that peculiar curtain which contains the pupil is a most artificial structure of muscular fibres, painted in a regular manner, and, in different animals, under great variety. This is a remarkable piece of work to be executed by the mouth of an artery : by many such arteries, of course ; and yet that renders the result still more extraordinary. As far as we can see, or ever shall know, every such arterial mouth should be the same : yet there is one which manufactures nerves, another the tough globe, a third the brown paint, a fourth the cornea, a fifth, a sixth, and more, the membrane, the muscular fibres, and the different ornamental colours of the iris ; while others again must produce the ciliary processes, the crystalline fibres for the lens, its enveloping membrane, the cellular membrane of the vitreous humour, the water which

fills this, the aqueous humour ; and moreover, in a bird, the {bony ring ; besides nerves, and even the blood-vessels themselves ; to take no notice of muscles, eyelids, glands, ducts, and more.

The reader will probably be surprised at such a mechanical analysis of an animal structure, because it is never made. We either overlook all this, or take it all for granted when we do know what it is. We know that there it is, and are equally sure that there will be another eye and another animal as long as the world shall last : it cannot but be, and we are satisfied. We may be surprised to be told that such opinions, if a stupid negligence can be termed opinion, are but a belief in Necessity ; an Epicurean, though tacit, renouncement of a Creator. And how much better is he who does believe in a First Cause, as the cause of all this ? The God whose power he does not investigate, and whose conduct and mind he does not strive to penetrate, is but a word in his mouth ; while if he satisfies himself with the term “ law,” what other is his God than the Deity of the Peripatetic philosophy ? God is known by His power ; that power is known by His works ; and how shall we approach to estimate Him, unless we examine those works ? It is not by assenting carelessly to the term All-powerful, that we shall learn to feel what that power is : it is not by barely admitting Him to be the cause of all things, that we shall acquire a knowledge of Him : that only knowledge which He has permitted us to acquire in our present condition.

So necessary do I deem this mode of analysis, that I will pursue it yet further. I said that the material was blood, and the tool an arterial orifice. What the exact nature of this last is, we do not know : but we are sure

that it must be such, because the matter of the new solid is deposited from the circulating blood, while that is conveyed by arteries. And it is confirmed by the case of reparation under injury, where we can remove that superficies which is producing a new secretion and a new solid, so as to permit the unchanged blood to flow out ; having thus removed that point of the artery which is the manufacturing organ. There must also be different qualities of arteries or arterial orifices, since one kind could not produce the aqueous humour, another the bony ring, and so on : while those classes must be as numerous as there are distinct products. But that is far from all of the primary mechanism necessary to the formation of this structure. A single arterial orifice cannot act beyond its place, or deposit materials where it is not : there must be hundreds or thousands of such tools, in each class, and tens of thousands to produce the whole structure of the eye. In what manner again are those which form the globe, so placed and directed, that it shall be a globe, and that every part shall have its exact thickness ; or how do they agree to terminate their work anteriorly in an exact circle, so that the arteries producing transparent cornea shall execute their own work unmolested ? In any case, how do they know when to cease acting ; which, if they did not, the sclerotica might become a solid globe or a shapeless body ? Still more, by what possible contrivance, or what disposition of such tools is it, that the mathematical convexity of the cornea is for ever truly formed, in every animal ? This is not merely inexplicable ; if there be aught of marvellous in nature, it is marvellous. The production of the crystalline lens is even more wonderful. Its anterior and posterior cur-

vatures differ, and so does its density from the centre towards the circumference. These are difficult problems to be executed in such a manner; but they are the least of the total difficulty. That lens is formed of fibres, sometimes appearing as if produced from one fibre only, wound round and round, or otherwise regularly arranged, under different dispositions in different animals, and often under very singular ones; designed, it must be presumed, to serve different optical purposes, though we cannot yet conjecture what those are. No one artery could have produced such a fibre, or any one fibre, unless it had been a moving machine, and almost a thinking being; and in what manner, and under what disposition of arteries, was a single thread produced by many? How is there even a fibre, or any crystalline lens? it must have been a mass of arteries: it should be a mass of arteries and veins and absorbents now, since it is nourished and repaired.

It is quite impossible to form any idea of the ulterior actions, or of the ulterior structure, in this case: and the same analysis and reasoning apply to every part of the animal mechanism. I chose the eye, as a well-known and not unpleasing object: the reader can extend these views, from the original structure of every part of the organization of an animal, to the growth, the secretions, and the repairs; since the tools, the materials, and the process, are the same for all. And if he does this, he must widely extend the number of these distinct tools or qualities of arteries; for there are many more products than those which unite to form an eye. Nor will aught be gained in point of simplicity or facility, by supposing that a single artery performs all, by changing its mode of action or its secretions;

since we must then ask how the arteries forming sclerotica change their conduct at the precise mathematical boundary of the cornea.

Yet even the entire structure of any one animal is but the least part of what is executed in the same manner : by the same minute instruments and from the same materials : since thus have been produced all the animals which crowd the world, in all the complications of their endless forms and mechanisms. One atom of artery, which no power can distinguish from the initial artery of the chicken, was the foundation of the whole ; by its branches all their parts were formed ; and by such branches, such orifices, are they reproduced in their posterity through all generations.

If such is the instrument, what must the Artist be, and what the power ? Incomprehensible it is, in the common meaning of that word : and yet I trust that the reader will now better comprehend this incomprehensible, if I may use such phraseology. He saw nothing before, and he considered nothing : if he has not seen much now, his reflections can at least take a much more just turn. Before this, all was a mystery : if it was not a “ principle of order,” or a “ necessity,” since no one of sound mind, and believing himself veracious, will now assign all this to chance : it was a Deity working by a word, without means,—a Being so remote from all possible conception, that it was fruitless to think of Him ; as even thus has He been forgotten ; forgotten, even till He was in danger of being rejected. There is yet abundant mystery : but we can now at least see a God working by means, by instruments : He is brought before us, so that we must behold Him ; since He is displayed to us even as a human artist might be : but He

is before us in all the fulness of His incomprehensible power, since His means seem as inadequate, as the works which they perform appear impossible. What power but the illimitable could have produced so many and such different parts, such various, such complex, and such yet unnumbered machineries, by means of one instrument and one material : reproducing them too for ever, according to patterns which never vary, complicated and diverse as we see them to be ? All must judge as they feel : but I shall be surprised if those who never reflected on these subjects before, do not join me in considering, that the Divine power is more fully and strongly displayed in the creation of a single animal, than in that of the great celestial universe.

That I might simplify the preceding view, I have hitherto spoken of an instrument and a material : they are terms that require further explanation here, though the reader is already aware of the facts, from a former chapter. The materials of the egg, whence the chicken is produced, are familiar : though we do not know the separate offices of the yolk and the white, consumed as they are at different periods. Nevertheless, the first assignable produce is blood, as that continues to be the produce of food during the life of the animal. I need not describe what is known of the composition of this substance : it is here sufficient that it supplies every production, solid and fluid, of the animal body. The office of the artery therefore is, to produce from it the exact substance which its duty requires, be that bone, or fibre, or whatever else. It is therefore a chemical, as well as a mechanical instrument ; making the needful material first, and depositing it afterwards ; like the bee which converts nectar into honey, and then places

the produce in its cell. Every separately qualified artery is therefore a distinct chemical apparatus, however resembling any or every other in appearance. There is no analogy in extra-organic chemistry by which this can be illustrated, because we cannot hitherto compound or decompound in such a manner : but we can at least imagine it possible, that a given number or arrangement of galvanic plates should produce a given effect, and that another should produce a different one. It is a presumption, I need scarcely say, that these powers depend on the sizes or shapes of the arterial orifices : but unable to conceive anything else, this can be adopted for the present purpose, without leading the reader into error.

Commencing therefore from the initial artery in the chick, it follows that it must produce, in the progress of its ramifications, as many distinct species of chemical apparatus as there are animal products, independently of its other action in producing the intended animal according to the commanded pattern ; while these chemical instruments differ also in many animals, in numbers and modes which the least reflection on them will render obvious. This is even a greater wonder than the mere mechanism, wonderful as that is : it is the superaddition of a most complicated chemical apparatus to all the rest of the complexity, while the final result is that extraordinary laboratory which constitutes the body of a living animal. This indeed is the final purpose of all the intricacy of the vascular mechanism ; which, however, demands the presence of life that it may act chemically ; as, when that is removed, it ceases to act, and shortly falls to pieces.

The vegetable structure and growth furnish the same

reasonings and reflections. We know indeed much less of this anatomy, and quite as little of the physiology; yet there is enough visible for the present purpose. Commencing from the seed, as I did from the animal egg, I may take that of the Oak. Here, the germ is distinct: it is a miniature plant, but it assuredly does not contain a pattern of the future tree, and still less of all the trees, in an endless series, which might be produced by separation, even although this were granted as to the seeds. With regard to the process of growth, we cannot see what we do in the chicken; the opacity of the vegetable structure is an insuperable obstacle. Here indeed we may speak of prolongation as forming the basis of the enlargement: but this explains nothing, while vessels must also be added exteriorly, assuming them all to be parallel, or the plant could not increase in diameter. How this is done, we do not understand; and we as little know how the branches are produced, or how their vessels are related to those of the trunk. What little is known, is at least of little worth. We do not even truly know what all these vessels are, and what their structures; being sure only of that which consists in a single spiral fibre, twisted with the turns in contact, yet separable at a certain period of the growth. This at least is a beautiful piece of mechanism; and so is the pith under all its varieties of cellular structure. So is all that we can see, in fruits, in flowers, in the transparent *Chara*, the *Confervæ*, the leaves of Mosses, and more; and so doubtless is all that we cannot see. But we must be contented with what, after all, is but an imperfect sight: for we cannot truly make out what these structures are, nor can we conjecture their actions or purposes, beyond the flow of sap and that of peculiar secretions.

Notwithstanding this, we equally recognise the hand of the Great Artist, in a mechanism, and also in a chemistry, which we can neither imitate nor comprehend. And the same power which gives life, here also commands a pattern : impressing on the initial vessels of the germ, the effort and the power to construct that, and no other ; with the further power, as in the animal structures, of producing every vessel which is to construct the future plant, and every species of vascular laboratory which is to form its peculiar solid products and fluid secretions, by acting on water and air, or on materials contained in those. But it is by taking a single organ, a leaf or a flower, and by applying to those an analysis similar to the preceding, that we shall best see what the facts must be in this case.

The leaf of a plant is a very regular and definite form ; and, even exteriorly, often a beautiful piece of mechanism. Interiorly, we know that it is a very artificial and minute structure, and that it is a chemical laboratory, constituted on similar general principles to the arterial laboratories of animals, because it performs the functions of composition and decomposition under the principle of life. But the exact structure has not been assigned. The multitude indeed look on leaves, as they do on much more belonging to plants, in little other manner than as they look on a stone ; scarcely considering them as organized bodies, far less as intricate living mechanisms. But philosophers must not boast of their superiority ; when, knowing the mechanism, and admitting the life, they explain all the motions of the fluids, all the motions of the plants themselves, and even all the chemical operations, by the laws of mechanics,—laws equally operative in dead matter. We are even more sure of the living and

active power of the vessels in plants than in animals ; because there is no primary force, no heart to propel the circulating fluid, and because they continue to act when separated from their connexions. The arteries of animals might be dead tubes, possibly ; with plants, this would be impossible : when the plant is dead they cease to act, because they are then dead themselves, though in no other respect changed.

The vessels of leaves, be they what they may, act like the arteries of animals. They convert a small leaf into a large one, preserving the forms and the machinery ; depositing therefore solid particles in appropriate places, while producing those from water and air. Like the arteries of the lungs, they exhale air and water, and they also inhale both : and whatever the process be,—whether it belongs to this species of respiration alone, or there be somewhat more performed, it is through them that the food of the plant is in some manner rendered capable of being converted into the necessary materials of the growth and the secretions, since without them these processes stop. If they have been called the stomachs of a plant, that term is not very appropriate. Lastly, as they are acted on by light, they must be living and irritable, or muscular, were there not abundant other proofs of this, in their actions.

I need not however take the whole leaf, as I did the eye, for the purpose of analyzing the actions and numbers of the producing arteries : it will be sufficient that I take the hairs alone. It may even answer the present purpose better ; since it is only by exhausting these analyses, that a reader can be brought to reflect on such subjects, and to apprehend the extraordinary power by which all these things are effected. Hairs, down, are

looked at and handled daily, without thought, as sand might be ; and the common feeling is, that such trifling matters come of themselves, as things of course ; a feeling which, persisted in, is but an atheism.

Every hair of all the down which covers the *Stachys lanata* (taking this familiar plant for an example) is an independent and an organized body, in itself. It is a minute vegetable, growing out of a vegetable ; it has its root, which is a gland, and there must be an artery for that gland, as there is to the bulb of the animal hair, without which the primary material for the construction of this vegetable one could not be deposited. That, like the animal hair, it is itself organized, we are sure ; but I need not now notice this additional mechanism. Let any one examine one of those leaves, and ask himself what must be the numbers, merely of these hair-making arteries, independently of all the others which must be there to construct the leaf itself, and to carry on the functions of respiration, or digestion, or whatever it be. This indeed we cannot see : but it is an anatomical analysis, a sort of dissection, by inference *à priori* respecting what must be. And thus we become equally sure that the interior anatomy of every leaf is not less beautiful, complicated, and minute, than that of the animal body in every part. Should any reader doubt, as all may doubt a mode of reasoning so new, he may look at the stem of the common blue *Veronica* (*chamædrys*), where certain hairs, very regularly proportioned in a gradually increasing length, are placed on opposite sides of a limited portion of the stem, in thin rows ; as, in Chickweed, there is an analogous, though different distribution : assuring us that some arterial laboratories or

glands have been placed there only, and moreover, doing their several duties so nicely, that the summits of a hundred separate hairs never deviate from the prescribed line. And if I said that the hair itself was organic and living, the proof may be found in *Myosotis*; since, without such subsidiary vessels and powers, there could not be hooked and straight hairs both, on the calyces of its flowers. The same conclusion may be drawn from the variations in the hairs of other plants; for instance, in those which are forked at the end, as in *Alyssum* and *Apargia*; or branched, as in the foot-stalks of the Gooseberry and some *Hieraciums*.

This might suffice to prove what the wonderful mechanism of plants must be: while we must not forget that the Power which constructed it, formed all this machinery out of air and water, out of materials from which our own chemistry has not yet made one of those solids; with difficulty one solid, and that only charcoal. But I must also ask whence comes this exquisite machine, not produced once for all, like the limb or eye of an animal, but reproduced every year, in myriads, from a point, from nothing that we can see, and thrown away every year by the hand that made it, as if it were a thing of no value. There is a period in every year, in which there is not even a leaf-bud, nothing but the interior vascular structure of the branch, which we conjecture or know. The bud must be produced by some vessel or vessels, some artery. And it is the equivalent of the initial artery in the animal germ; for it can produce an entire new plant according to the appointed pattern, as it does in the Strawberry. And what is the mechanism, when this active initial artery may exist anywhere, or everywhere, as in the Elm, where the

shoot will grow from almost any point ; or as in the plants without end that produce roots wherever they touch the ground, or as in the leaf of a *Hoya* ? The initial artery cannot have been formed and dormant at all those points : it is the produce of the ordinary ones ; while it produces in turn all the subsidiary arterial laboratories which are to form the several parts of the new plant, just as those had done before : proving the entire analogy of the proceedings in the animal and the vegetable structures.

But no hypothesis will diminish the wonder : while neither the mechanisms nor their progress can be disputed. It would be even more wonderful, were the plant a mechanical agent ; not a living being, acting from the impulse of some sentient and energetic principle, as the animal does, and though without consciousness, not more unconscious than this is. That indeed would be as if a wire could shoot out into a steam-engine, because it was placed in contact with iron filings. What does philosophy propose to itself by such hypotheses ? It once indeed thought thus to prove that there was no God, or a God who acted not and cared not. It must be owned that its logic has been as sound as its piety. What does it mean to prove now ? it would be hard to say. Its philosophy ought at least to be better, for it knows more : but its logic has not improved.

Let it consider the remainder as it pleases ; for I need not argue further. If there are one hundred thousand species of plants, as has been supposed, there must be one hundred thousand kinds of initial arterial laboratories in the seeds, as there are many hundred thousand kinds in the eggs or germs of animals. These

are the pattern-forming arteries ; but they also produce the several subsidiary ones, which are the laboratories for the different parts and products of the plant : and when we recollect the different mechanisms, products, secretions, the leaves, flowers, fruits, seeds, thorns, hairs, and far more, in each of these several plants, with every distinct point or part and quality in those different things, through every individual of all those thousands, the mind becomes absolutely bewildered in the contemplation of the power which thus has wrought, and thus works for ever in the production of all those mechanisms, as unfailing as they are numerous and complicated. What more indeed could it feel under similar reflection on the animal machineries? For these indeed, it must multiply all this many times ; but where the less is incomprehensible, to what purpose attempt to sum the greater? I repeat, that I at least see nothing in the starry heavens to be compared to these exertions of power : or, in philosophical language, the laws of organization convey to myself a far deeper feeling of the Creator's power, than those which formed and preserve the great system of the universe.

The analysis of a leaf was comparatively simple : that of a flower is not less intricate than that which I gave of the eye. In whatever manner the Rose commenced, it was once an invisible point : but as it enlarges, we find it folded and packed with the utmost nicety, under a pattern of folding which never varies ; as is equally true of leaves, and of all leaves, and all flowers, each according to its own pattern. And though one or more principal arteries may form the basis of the whole flower, hundreds must conspire to produce even this simple and almost unnoticed package, as all must work

with unvarying constancy and precision. They work indeed as if they had all but one mind : and truly they have but one, while that mind is the Creator's. But the rose is at length unfolded to the day. Even in material, we are sure that the same species of arterial laboratory could not have produced the green calyx, the flower petal, the pollen, the horny coat of the seed, the seed cotyledon, the germ, the hairs within the capsule, the capsule itself, the hairs without, the resinous glands, the spines, and more, if more of different material there be. Botanists indeed have called the calyx and the petals prolongations of the outer and inner bark, as, by a more recent and equally absurd theory, the petals have been considered as leaves, and the leaves as bark. This may be philosophy, but it must be tried by common sense. It is true that in plants, parts are rendered convertible for certain purposes, but this does not prove that they are the same : their distinct functions, structures, and forms must be considered. Such theories are the abuses of a scholastic logic, by children in even that misnamed science ; applying formulæ as if they were facts, and where they are totally inapplicable. The favourite term prolongation must be explained by the botanists who use it : it might as well be said that the crystalline lens was a prolongation of bone ; as it has even been said that the cornea was a prolongation of the skin. Chemistry at least will decide that different secretions must have been produced by different chemical organs ; and, of any other resemblances, an ordinary mechanic may be safely allowed to judge.

But the numbers of these generating arteries demand not less attention than their separate chemical powers. The mere spine is a horn growing on the bark, and

of a very constant shape in each species. It once adhered by living vessels: having done their appointed duty, they die, like those which produce the horn of a Stag, and it becomes separable. It was no small mechanism which shaped the straight or curved spine of a Rose, as it was a peculiarly chemical one through which that spine is not wood or bark. The slender and separable connexion of the petal, which seems almost without adhesion, shows how few were the vessels which initiated this beautiful structure: while new qualities, and thousands rather than hundreds, must have existed beyond them, to produce that unspeakable delicacy and beauty of construction which I have noticed in a future chapter (c. 47). Still further, there are stamina, bearing capsules containing hollow and detached spheroids filled with other scarcely intelligible substances. This is a most complicated piece of mechanism: let a mechanic imagine himself obliged to imitate it, on any scale that he chooses, and in his own way. Yet every globule of pollen, to omit all notice of the capsule and the filament, must once have been attached to a vessel extending from one or other of these. Every hollow sphere must have been formed, not by one vessel, though one might have secreted the internal fluid, but by many. By how many? Magnitude or minuteness is nothing in this case; it is a hollow sphere, the case of the globe of the eye on a smaller scale; and it is not one vessel that could have produced a single globule, as there are hundreds of such globules in every capsule, and perhaps fifty capsules in a single flower. Were there twenty, or fifty, or a hundred arterial orifices employed in forming each capsule of all this pollen? the largest number may be less than the reality. I said that the formation of the eye was an incomprehensible problem, but that

of a flower is still more incomprehensible : while the eye is made but once, and the flower is wasted and renewed annually ; produced, in the *Cistus* and the *Cactus*, to die or to be dissipated in a day, as if it were nothing. We have been desirous to wonder at the construction of animals, and at the animal mechanism : philosophers have forgotten that the growth, the production of plants, and their parts, were still more wonderful ; and that the minuteness, the beauty, and the intricacy of the mechanism were at least not inferior.

If it would be long and unnecessary to analyze the whole flower in the same manner, I may still point out the seeds. How many vessels must conspire to form the capsule alone, how do they begin, end, agree that it shall be of a certain precise shape and thickness ? In that of the *Rose*, the surface is covered with hairs, and the inside is filled with them : and I have shown that each hair demanded its own producing organ. It was not one vessel that formed all the seeds ; nor could a single artery have constructed even one. The horny coat alone is not the work of one, any more than the coat of the eye, unless one vascular orifice could be everywhere. The two cotyledons are full of vessels ; the germ is a plant in miniature : and here at least we are sure of the multiplicity of the vessels, whatever hesitation might exist as to the former cases. Had the mechanism not been what it is in the full-grown plant, the germ could not have been what it is, neither could it have proceeded to fulfil its destination : and what the minuteness of those vessels and that mechanism must be, all can judge, though they should examine the seed of a *Bean*, not that of a *Mignonette*, a *Streptocarpus*, or a *Moss* : or the nearly invisible *Reticularia*, which is said to contain millions of germs.

I must not pass over an important conclusion which may be drawn from some of the preceding facts, though this inference has been necessarily made elsewhere. There is an arrangement, or a law, or a command, through which the forming arteries cease to act at a certain time, or else the work would be marred. Whatever this be, it is not at least a strict decree, and therefore not a general law ; as further, not established from the beginning. It is broken every day, in the doubling and the other variations of flowers : the vessels defy all laws, when they convert stamina into petals, and when also they produce, in one year, a different variation from that of the preceding. There is therefore also no such thing as the "Necessity" of philosophy, and no such principle as the "principle of order:" since it is of the very essence of those to be unvarying. And if it is said that the Deity established from the beginning dormant laws, which might or might not be called into action, it is not easy to see what is gained by an hypothesis so complicated, of which the only object is to set aside His providence and government.

But it also follows, if more proof of that were necessary, that the producing arteries are living, though not conscious agents ; as they are in animals. No purely mechanical machine could thus vary its actions : should a ribbon loom produce damasks, we should be sure that a superior power had altered its machinery and conduct. The instinct of an insect is a rule of conduct, and thus far it is a machine ; yet not the machine which it has been called, since it is moved by the mind of the Creator. But it is allowed to break through its rules when necessary : and thus the Bee, under an allotment of reasoning powers, deviates from the law for its architecture, when hampered by its hive. Through what means the Creator

has given the similar licence to plants, is what we do not know : but what cause for surprise is this, where all is ignorance ?

I have hitherto spoken of pattern-forming arteries in the plant, but without explanation, as I purposely omitted this under the analysis of an animal. The whole forms an important question under the power of the Deity, which could not have been sooner examined, as it could not have been understood before. Former hypotheses, modern and recent not less than ancient, adopting the equally thoughtless and vulgar explanation of the process of growth through expansion, extension, and prolongation, were obliged to have recourse to another invention, that, namely, of pre-existing germs in the egg and the seed, perfect in even their minutest parts, and requiring therefore only this fanciful enlargement to attain the ordained size. But it is indifferent though the hypothesis of these miniature germs were independent of the contrivance for the growth under the other one : while it has also forgotten to inquire, in what manner and by whom they were formed ; as has been usual in that philosophy, ever labouring to rid itself of an imaginary difficulty, yet not perceiving that it was leaving an equal or greater one behind. The question of successively involved germs I have been compelled to examine under the inquiry respecting imparted lives ; and need only therefore say here, that it involves a mathematical impossibility. And being impossible, the hypothesis of a single perfect germ is of no value for the imagined purpose ; even if that were no more than to get rid of the difficulty which relates to the growth of a plant from a point in the seed, or an animal from an excluded egg. The germ itself, in both cases, was formed by one artery, or possibly more, ramifying from

the arterial system of the parent : and that which such a vessel could execute in one place, a similar one could equally perform in another, being provided with life, as we know it to be. But the facts alone are a sufficient answer to this hypothesis : the only marvel is, that they could have been overlooked. I have already noticed, in the animal, that even the annual renewals of the feathers, through years, are inexplicable on such a supposition ; and it is the same as the annual coats and the deciduous horns of quadrupeds are concerned. To imagine a hundred successive sets of the feathers of an Eagle included in its germ, is to suppose a mathematical impossibility equal to that which is involved in the greater hypothesis on this subject. The same reasoning applies to the animals which are capable of reproducing new parts ; though such is the ardour or blindness of hypothesis, that even Reaumur asserts that an original egg, or germ, for that special part, must have been prepared at the points whence the new legs of Crabs grow after having been cast. The answer, from a consideration of the proceedings of plants, is still more overwhelming : it even seems a childish superfluity to name those ; yet it cannot be so, when they have been overlooked by these philosophers. The annual production of leaves and flowers through centuries, is a stronger answer than even that from the feathers of an animal : the reproduction of plants through dismemberment is still stronger ; since an entire forest might thus have been contained in the seed of the first plant.

Far less than this ought to suffice. I have shown that in the plant, it is a vessel, or vessels, in the germ, which produce every thing ; and could this power be denied, it is proved by the fact, that many vessels in the full-

grown plant are empowered to produce, not merely the parts, in leaves and flowers, and branches, but full-grown, and even detached plants, similar to those from the original seed. The power of forming a new plant has been given to many vessels, not to one alone. I have termed it an artery, because of the analogy of its action to the producing arteries of animals. And it is the same in this department of organization, though the productive power has been generally limited to the vessels in the germ ; a few exceptions only occurring in the inferior animals. That which is visible in the proceedings of the egg, is almost an ocular proof : while the difficulty in this case is even less ; since, with the exception of the clothings and the new germs, the parts are produced but once for ever.

I need not pursue this preliminary inquiry. If it were not thus proved, directly, that the power of forming the organization according to a pattern, is given to an entire vessel, it is proved by dilemma ; since I have shown that this pattern is not pre-existent in any manner, or at any period anterior to the growth. And it is given to all initiating arteries in each set of organizations, although one acts on a different set of elements from the other, producing distinct compounds ; more distinct indeed than the essential portions of the mechanisms always are. That in certain animals and in many plants, the same initiative and pattern-forming power is also given to other vessels, not belonging to the germ, I need not repeat ; as I need not say that it is also given to some vessel or vessels within animals, for the production of their own germs.

This is the great mystery of organization ; and it defies all power of comprehension or conjecture. When

we look at the first atom of artery which appears in the egg, we must believe that not only is it empowered to produce the entire succession of arterial laboratories, but the established form of the bird, according to a pattern which is the rule of its action and conduct. Yet there is nothing to distinguish the artery in the chicken egg from that of any other egg; and could we see every such artery of each germ through the whole universe of animals, we should discover nothing more, and no difference probably but in magnitude. We may believe it to be the same in plants, though we cannot discern those vessels. In each case, these living atoms, or fragments of tubes, are placed in contact with appropriate materials, each with its own chemical compound; when, under the power of life, they proceed to form their several machines according to the patterns commanded; while those patterns are hundreds of thousands, though these instruments cannot possibly differ, in the least numerical proportion to this vast sum. If the reader to whom such views are new, will conceive a number of tubes plunged into a fluid, and, from this, producing at their extremities as many different animals or plants, it will be scarcely other than the fact in question, as far as we can see or conjecture what that is.

If this power to form a machine according to a pattern has been impressed from the beginning, it is the "law of organization;" whatever that favourite phrase may explain. But if there be such a "law," there must be hundreds of thousands of laws of organizations. One law of gravitation might have made this earth, and every other globe in the universe, what they are: but it required fifty thousand laws at least to produce the

plants alone that inhabit one of those globes. Would even that number suffice? If it would, where is the metaphysician to explain how laws issued at the Creation acted on that which was not yet in existence,—how a command can be impressed on a nonentity? I fear that philosophy must still have an unwilling recourse to a governing power, to that First Cause which rules and directs, to-day, and at every instant, everywhere, as it has ruled and directed at every moment of all eternity. But explain it as philosophy may, it was God, it is God, who commands to all these unintelligible atoms of instruments, the patterns which each shall follow, and who thus fills His earth with those not less incomprehensible mechanisms to which He has imparted life. Can His power be more strikingly displayed than it is in this; and did I say wrong when I said that it was more visible in the living creation, than in all the numbers and the space and the magnitude of the great universe?

If I have thus sketched two analyses in the animal and the vegetable world, they are rather general than minute: it is necessary to examine a few objects in more detail, as there is much yet remaining with respect to this particular demonstration of power.

The butterfly is a convenient object for this purpose; but I need only select portions from the whole. As I have elsewhere explained, the egg contains two germs; one for the caterpillar, the other for the representative of the parent. There is not the mystery of transformation once supposed. But it is a sufficient mystery, that the one germ has become a perfect animal while the other is lying dormant. Passing by the complicated structure of the caterpillar, the germ of the

butterfly begins to act as soon as that has fallen into the torpid state. Its generating vessel absorbs the nutriment prepared by its predecessor, as the chicken does the material of the egg; and the remainder of the process must be the same, though we cannot see it. But the beautiful package of this animal in its secondary egg, demands that notice which the chicken did not; it resembles those of leaves and flowers, as the formation of all the parts under this constraint adds much to the apparent difficulty of the whole process.

Neglecting its interior anatomy, yet not forgetting that, under this minuteness, it is not less complicated than that of a large animal, there are six legs; and a sufficient general notion of their construction may be formed by examining that of a Lobster. All these were formed in that close package, under all their accuracy and minuteness of shell, joints, muscles, tendons, blood-vessels, nerves, and more, by arteries: and thus also were produced the spiral and jointed proboscis, the antennæ, the complicated eyes, and much more in the exterior anatomy which I need not describe, since all can examine it. The hairs alone demanded each a separate artery, as in plants; while the precision in the lengths of these bespeak an equal accuracy in the actions of the vessels. What the similar precision must have been in all the other minute parts, I need not say; while not less must have been the chemical accuracy of these minute and incomprehensible laboratories, since the error of any, secreting shell, instead of muscle, or aught else, would have produced confusion or failure. In many animals, such errors do occasionally occur; the wonder is, that they are not perpetual: yet thus also is it proved that there is no "necessary" conduct or law of "order."

The compound eyes, however, demand a more detailed examination : on any scale, they would leave the difficulties respecting the single quadruped eye far behind : on the present, and there are many far smaller, the procedure for their construction bewilders the imagination. I might name the Drone, examined by Hook : the Dragon-fly furnishes an even more striking example, if Leuwenhoeck is correct : but the same description may be applied to all of those extraordinary pieces of mechanism. There is a spheroidal hollow shell perforated by holes, which amount to 7000 in the former insect, and upwards of 12,000 in the latter : mathematically true, and each of them containing a cornea, or a lens. If we look at the precision of the workmanship, the number of the parts, the difference of the materials, it is fruitless to attempt conjecturing where the arteries that produced all these things could exist, producing them also point by point. How many were required for each hexagonal opening alone ? and yet how few were these out of all that must have existed to produce the retinae for each, with that interior complicated structure which I need not here describe, and that nervous branch which terminates in each retina. Whether we consider the diversity of the chemical compounds, with the consequently different powers of the vessels, the precision of the workmanship, or the necessary numbers of the arteries, we should say that it was impossible to construct the insect eye, and, above all, to construct it by such machinery. Yet thus, and no otherwise, could it have been constructed ; while all this complication of a perfect arrangement was produced by one artery originally, in that transparent fluid which is the visible germ of the insect in the caterpillar.

Here also were formed the wings of the butterfly,

once vascular and living, though apparently insensible or dead, at least as much as feathers are, in the flying animal. The framework of this organ is tendinous or horny; and the membrane is covered with "feathers," which are similarly constructed, and grow out of the former by a pedicle, being also of different shapes in different places. To pass over the whole substructure, each feather must have required its own artery; while I must now add what I have always omitted before, lest I might further encumber a sufficiently difficult subject, that every artery must have had at least its vein, with probably its absorbent, if not also a nervous branch. Even this great preparation for executing a temporary work, to die after it was done, like the arteries of a deer's horn, is not all. The wings are coloured, and we have reason to believe that those colours are produced, partly at least, if not solely, by reflecting surfaces demanding very accurate and peculiar mechanisms. What then is the accuracy of the instruments which produce those, the precision and the minuteness of workmanship in a wing of many colours and determined patterns? Can any one conceive the distribution, the numbers, and the actions of the arteries in the wings of the Argus? or the accuracy and constancy, which in millions of wings and hundreds of patterns, never produces a misplaced colour or a false pattern. But not even could one artery have produced the coloured feather on a butterfly's wing. As well might that which supplies the capsule or initial quill in the feather of a peacock, have formed the coloured star at many feet in distance. A further vascular mechanism there must be, even in this minute object: it is for the reader to imagine what it can be.

But this mechanism, like all the rest, was produced in a close and complicated package. We must ask what were the calculations which placed these different vessels, even when in their native fluid, which guided them, as the wing became formed, in such a manner that the whole pattern, in shape and colour, should finally come out true. The carpet-weaver must calculate deeply, that his far simpler web may be truly drawn and coloured: but it would pass all human skill even to approach to such a calculation as this. The Divine artist must have done the same, or His work would have been marred; for He too wrought by tools. Special arteries must have been prepared for each colour, and there must have been a determined number of each: they were compressed together, and wrought in a mixed crowd, while the membrane itself, and all the feathers on it, were also produced, not as we now see them, but in a fluid, whence a flat picture was afterwards to issue. What must have been the calculations, that so many hundred arteries, springing from one trunk, should have all possessed such separately precise and proportioned lengths, were it no more than this, that when the wing was expanded it should be flat; what further calculation placed each feather-making point so exactly, and that for each colour in such a manner, that not a feather should be misplaced, that there should be no error either of colour or outline? Such calculation and such a process are inconceivable. Yet the Creator did it thus, and no otherwise. He does it thus for ever: for hundreds of species and millions of individuals annually; for hundreds of thousands and incalculable myriads, in other insects, every year, as He has done the same from the beginning of Creation, and will do it

as long as the earth shall last. And His instruments are incommensurable atoms, as His materials are the invisible elements of the atmosphere. This is Power : and I am not yet weary of repeating, thus is His incomprehensible power best displayed.

The uninformed reader may possibly yet doubt that all these different arterial tools, possessed of so many properties, can be the produce of an arterial trunk of no peculiar quality, or of no forming or secreting power ; as even others may dispute views so novel, yet, only novel because this subject was never before analyzed to its exhaustion. But we are as sure of this as that the arteries which form the eye grow out of the carotid trunk, or that the fundamental vessel of the bud generates all the separate arterial laboratories which form the different solid parts and fluid secretions of the flower. The production of a feather shows this even more nearly ; since it is an ordinary branch of the humeral artery, circulating blood only, which produces that peculiar artery, and, successively, the other obscure vessels of that structure, which form its various parts and secrete its several colouring matters. But the proof is rendered perfect by the case of ulceration and repair, already quoted. I formerly showed, that under this proceeding, there was an arterial orifice, or instrument, secreting a new fluid, and forming the new required solid, in proof of the assertion that all the animal structures were produced by such an apparatus. The same fact equally proves that all such ultimate arterial laboratories are generated by the ordinary circulating branches, because they are renewed by those, in this case, as often as they are separated by the knife. It has indeed been said, that these or similar operations

were conducted by cellular textures and by pores ; and such a hypothesis has been asserted of insects in particular, even by Cuvier, to our justifiable surprise, when he says that secretion in them is performed by a long vessel whose sides absorb and transmit like a sponge, and that their nutrition passes from the intestine, through pores, to all parts of the animal structure. It is difficult to conceive such reasoning possible, even in the meanest anatomist : the authority of this one, great as it has been reputed, for whatever reasons, claims for him no exception from a censure which I gladly leave to others.

And while nothing of this nature can be seen or demonstrated, it is a gratuitous hypothesis, for no purpose ; while equally unphilosophical and awkward. In the larger animals, the continuous vascular structure of glands, from the entering artery to the issuing duct, proves, not less than the preceding fact, that secretion is carried on by tubular vessels ; and when we trace the larger vessels in insects, why must we suppose the structure changed, merely because it becomes invisible ? As well might it be denied that the minuter ones had any blood-vessel, because we cannot discover it. This is to renounce all analogy : philosophy may reason inconsistently, but the conduct of nature is ever consistent. It is as awkward a contrivance also, as it is an unphilosophical one. Cellular textures are held to possess a general communication : and it may be asked, not merely how such a texture could carry on a circulation, but how any pores in it could separate so many different substances from the contained fluid, and, in the case of the solid deposits, apply them with the accuracy that we know. No mechanic could suggest the necessary

disposition of such pores ; while, being living and muscular, without which they could not act, there is not an anatomist who could contrive the necessary muscular arrangements. In the case of vessels, there is no difficulty of any kind.

As this inquiry was necessary for the reader's satisfaction, so must I pursue it through the remaining cases : especially for the sake of those who now read on science, and do not read enough : reading the last new hypothesis only, and believing what is boldly asserted. I have represented the vessels of plants as tubes, even to the ultimate working laboratories ; as I have, analogically, termed them arteries. But this structure also has been asserted to be cellular. It is true, that there are visible cellular structures in plants ; while, except in the case of fruits, where they are used for dividing the fluid, we do not discover their uses. That of pith is assuredly far too large to be employed in the minute operations which I have been describing ; and that appearance of a very minute one which is seen in the transparent *Chara*, is more likely to be a valvular disposition in a prolonged tube. But the objections already made in the case of the supposed animal cellular textures, apply equally to this one : while we can but wonder at the anatomical and chemical knowledge and reasoning, which contemplate the circulation, secretion, and growth of an animal or a vegetable, as they would the passage of water through a sponge ; which, because they can effect something similar by means of dead matter, view the living organization as a dead structure, at least in its ultimate parts, operated on by foreign, and almost accidental causes ; as if nature had trusted matters of such importance to chance.

And the same argument from the consistency of nature applies again. We know that the primary vessels of plants are tubes ; and wherefore then is the structure to be changed in its progress, above all when it is continuous in the animal organization ? It is an argument which rests on a double foundation : and they who reject it ought to demonstrate their own cellular organs, or, at least, produce an analogy ; if not show in what manner such a structure and such pores as are presumed, ought to be constructed and might produce the necessary effects.

This is the very wantonness of gratuitous invention ; since the work is already done without it ; and it must not be said that it could not be thus done in plants, for want of a heart or a prime mover. Whatever be the source of motion in their larger vessels, the activity of the circulation is very great ; and that force is the sufficient prime mover to the ultimate ones. It is true that the circulation in plants is difficult to be seen, not only from the opacity of the vessels but from the transparency of the fluid ; but whenever there are globules it is visible, and for obvious reasons, as also in the milky juices. Those who say that this circulation is not continuous, but a motion backwards and forwards in short spaces, should be sure that the microscope shows the truth. But the latest of all the new theories asserts that all the secretions are performed, not by living, but by inorganic pores. It is easy to see to what class of philosophy this belongs ; while it is the misfortune of all these new modifications, to forget the safe rule "*salus est generalibus*," and thus to make that display of ignorance and clumsiness which their less informed, if not wiser, predecessors had avoided. Could

such a theory be true, it would end in disclaiming all that belongs to organization and living forces: an ingenious mechanic might perhaps construct a plant or an animal; or at least the dead structures might conduct the business of life.

That I may terminate with these unavoidable physiological inquiries, and also bring the whole into one view, I must lastly note the case of feathers; including, of course, hairs, and whatever else there is of analogous, even to the wing of the butterfly already examined. That these are vascular, as I have represented this last object to be, is proved by the facts of deposition and absorption after the completion of the growth. The colours in a single feather are changed in this manner between the summer and the winter, in some birds, as the hair is in many quadrupeds. These vessels also, be they what they may, spring and are renewed from an ordinary arterial branch, as I already said; while they are also affected by acting on that, as happens in the production of fanciful colours in pigeons, and in the conversion of one colour to another, in hair, or in the disappearance of all colour; most remarkable when it takes place suddenly, through impressions on the nervous system. But there are no means of demonstrating their tubular structure: I can only infer it in the same manner as I have done in the case of vegetables. We indeed find a cellular structure in them, as we do in those; but while it cannot be accurately made out, it is more likely to be merely that arrangement through which strength and lightness are attained; as it is also the basis and support of the truly circulating and active vessels. It is abundantly plain indeed, and very obviously in so large a structure as that of

the pith of the Elder, that the cells could not form themselves, and that they must be indebted to some prior machinery for their very existence, as much as is every other part of a plant or an animal. I need not draw the same conclusion again; yet must not allow the reader to suppose that the true artery is ramified through the feather, and that there is a continuous circulation through it, as in the eye. The primary impulse appears to end at the generating capsule; and, beyond this, all the actions seem to be carried on as they are in the vegetable structures, by an active power in the vessels themselves, whatever the nature of that may be. Speaking somewhat metaphorically, they are plants growing on an animal body.

This will suffice, as it will aid the reader through the analyses that remain, so that he can now follow them with greater confidence. But as far as the power of the Creator in producing organized bodies is concerned, it is perfectly indifferent what system is adopted: since the minuteness and intricacy of the workmanship, the accuracy of positions and of performance, and the equal accuracy of the chemical actions, must be the same, at the very least, under either theory, or under any other one that may be proposed: since, without that, it is very certain that the work could not be executed. There is no magic in the works of nature; there are causes and means for every effect; though we do not always discover those: and though God operates by a word, that word acts as philosophically and reasonably as the hand of man; in chemistry, according to the rules of that science, in mechanism, under the laws of mechanics.

Choosing the next example of such an analysis from the vegetable structures, I may take an Orange; as its

larger mechanism is very obvious and easily examined, and as I formerly pointed it out among the examples of mechanical design. The few vessels on which the whole of this artificial and multifarious work has been built, pass through the footstalk ; and here they are the ordinary circulating ones of the plant. But their progeny produces many fluid and solid secretions ; including, with water, sugar, acid, mucilage, essential oil, the principle of odour, membrane, the spongy skin, the external yellow one, and the seeds, with their several parts. This is a very complicated chemical laboratory : but the necessary mechanism of the vessels is still more wonderful under this method of analysis. It must have required four vessels at least to produce the fluid within each of the internal capsules, unless one gland can perform two or more chemical functions : it is likely that there were more than one of each kind for every one of those numerous receptacles. Not less than one was necessary for secreting the oil in each spherule of the rind, if indeed the elaboration of the matter of odour, which is separable from the oil, did not demand another organ of a peculiar chemistry. But let the reader turn back to what I have said respecting the formation of the globe of the eye and the pollen of flowers, and then ask himself how many vessels were required to produce each internal capsule, and each external and beautifully accurate spherule, what courses they held from the primary arteries, and where and how their orifices were placed ; did he even omit all notice of those which formed the two rinds, the enveloping membranes of the divisions, and the seeds. An Orange is not the inorganic body which ignorance and familiarity imagine ; nor did it construct itself ; even in the manner which I have shown,

was it constructed ; as thus, and no otherwise, has every vegetable production been made. Could the mechanism of this common object be displayed to us by injection and dissection, as that of the animal body is, it would surely not prove a less wonderful piece of machinery : or could God communicate to us the power of seeing everything as He sees it Himself, the most thoughtless would acknowledge that hand which the reflecting mind can thus trace, even as if all those invisible works were displayed before the eyes. Let the reader, if he pleases, pursue the same analysis through the fruits, where a feeble but complicated cellular texture, as in the Pear and the Peach, confers a temporary solidity on a fluid : I will turn back to the animal organizations, and to a feather ; because this also was one of the mechanisms formerly pointed out for its beauty.

The germ of a feather is a capsule receiving an artery, and the quill, filled with blood, is the obvious basis, to a common eye. By degrees, the plumes push their way through it, and expand ; the cavity of the quill is dried, while the pith remains to mark the seat of the vessels, and the feather becomes an apparently dead, as it is an insensible structure. It is not dead however, since it performs the occasional functions which I have just described : it cannot be without nerves, since it contains active vessels ; although it is insensible, because a sense of feeling would have been injurious : being thus one of the examples of that singular exertion of Divine power which I have examined at some length in an immediately subsequent chapter. The hollow quill, I need scarcely say, passes into a thinner one filled with a beautiful cellular texture, channelled on the inside, producing down, generally, below, and upwards, opposed

rows of blades, each bearing hairs of a peculiar form, by which the adjoining edges become entangled so as to produce a firm plane.

This is a very general description ; but objects so accessible and familiar do not require to be detached, especially for the present purpose. And the analysis of the growth can be pursued, for the greater part, in the manner already, and more than once, indicated. The reader himself can now inquire how many vessels must have ramified from the main artery, and how they were placed, to produce the several textures, first, of quill, pith, and so forth, and afterwards, each plumule and blade, and each hair on the latter ; to say nothing of the numerous secreting organs necessary to construct every single blade and every single hair, with every point of every cell in the pith, and every fibre in the quill. He may ask also, why, when every primary vessel of a blade must have resembled every other, those on opposite sides, in many feathers at least, are unequal, as the proximate ones on the same side also are ; yet under such regularity as to produce an unfailing outline, and that outline differing too in hundreds of feathers, yet for ever constant in the same, and constant through every annual renewal, though all these vessels must be annually reproduced by the common circulating artery. Every vessel producing each blade was independent, and all secreted the same matter : why did not all produce the same form and the same length ? The humeral artery also produces a branch for each capsule over the whole wing, and there is no assignable difference in these, since they circulate blood alike ; yet there is scarcely one that produces the same set of ulterior vessels or working machinery, since scarcely two feathers in a

wing are exactly alike. Let there be no difficulty therefore in believing that the initial artery in the chicken produces the whole animal according to the ordained pattern ; the fact is before our eyes, open to examination, and on a large scale : every artery in a bird which feeds a feather capsule, is an initial vessel, producing a new and a specific, definite, organization, and as constant to its pattern as the vessel of the chicken germ : while, doing this, what is there which an artery cannot do, under the orders which it receives from the Creator ?

The similar analysis of the Peacock's feather, formerly analyzed in another manner, and for another purpose, may show what must be the minuteness and complication of the vascular mechanism, even more distinctly. And it is indifferent whether the colouring were the produce of a chemical secretion or an optico-mechanical texture, or both. If I take but a coloured plume from the star, the reader can compute all the rest ; while the inquiry respecting the mechanical forms is the same as in the last case. Every point of every colour must have required its producing vessel, and every different colour and gradation of tint must have demanded one of different powers. The precision of place in all these, under their separate qualities, must have also been perfect ; since there is no error of pattern, either in colouring, gradation, or drawing. In millions, no error was ever yet discovered. Let the reader contemplate the entire star in this manner, and then form his own computations. But he must do more. That star was commenced, or calculated, in miniature, and in package, in the body of the quill : it quitted this place, it advanced with the elongation of that, to a distance of three feet, enlarging in its progress, and at that distance from its

obscure and unintelligible native seat, it is the accurate, the complicated, and the beautiful plane and picture that we see. It is the case of the butterfly's wing; but a far more difficult one, and requiring far deeper calculations. But if he will carry this analysis further, through the whole of this most complicated and varied collection of feathers, forming a single picture, as each star contains its own, I scarcely know how he can believe in that process which I have thus pointed out, or in that vascular mechanism which I have inferred. Yet this, or something not essentially dissimilar, and not more easy, must have been. He cannot take refuge in no cause: he may indeed satisfy an indolent and unreflecting mind by consoling himself with the thought of Almighty power, surely equal to the production of a peacock's train, he cares not how. But to permit this manner of viewing that power, is to have written in vain, since it is but an empty word. It is only by reflecting in the manner thus pointed out, that he will really see and feel this Power to be unbounded and incomprehensible; since it is ever executing that which to all human apprehension seems truly impossible.

One more analysis is yet necessary, before I quit this common and almost despised object, while I select it, as I have done all else, because the principles are widely applicable through creation. Each of those indeed is the head of a wide family; while, united, they will serve as a guide through all the organized forms of plants and animals. Taking any one quill feather from a wing, we see that it possesses a peculiar double curvature. How was this effected, when every portion must have been formed by a separate vessel; and why was it not continued in a straight line from that quill of

which it is a prolongation? It is a most delicate and difficult form to have been produced in any manner ; being even more so than the cornea or the lens of the eye ; yet it is invariable ; while mathematics cannot assign either of those curves. But if it is difficult to conjecture the mode of proceeding as to a single one of these feathers, what does this difficulty become, when we find that no two possess the same curvatures, in either direction, while all are double curves? The differences are of the most evanescent and unassignable nature ; while thus is the peculiar and necessary form of the wing produced. I need not say that all this is reversed in the opposite wing ; nor need I again refer to the mode of production, through branches of the humeral artery in which we can neither trace nor conjecture any differences, though every one for ever performs its delicate and difficult allotted and separate office. I know nothing in the whole circle of nature more beautiful and more incomprehensible than this simple and unnoticed fact. I need not pursue this particular analysis through the whole wing, as it is easily examined in the same manner. But had a mechanic planned a wing, and allotted all the portions, whether to one workman or more, we know well what the calculations must have been, and what the drawings, that every feather should thus unite to produce a single structure ; as we know that no engineer can plan even a far more easy machine, so that every part shall fit correctly and act truly for the first time. Yet we admire even these imperfect works, and forget to admire the Artist who planned and who executed, and whose most delicate and difficult works came at once from His hand, perfect.

Though the objects which I have thus analyzed, doubtless contain vessels and organized parts of the most extreme minuteness, the demonstrations of this are imperfect, except in the case of the butterfly and the insect eye; while the large sizes of the others prevent them from conveying that impression of minute workmanship which would be made by a smaller object. And as this is one of the most striking lights under which the power of the Creator can be displayed, I must proceed with these analyses towards that last known size of organization which exists in animals; since for this purpose I need not examine the minute vegetables. But as the difficulty, and therefore the power, is concerned with the nature of the materials, as I remarked at the beginning of this chapter, I must commence with noticing these, while they also form, in some cases, a distinct subject of interest under this question.

The feather just examined is one of those: and I need not say that chemistry finds but the same principles, and only slender differences, in all the animal textures; as we learn nothing towards the present purpose, by knowing the composition of any. The united strength and lightness of a feather are familiar. We say, habitually, that there must be some direct relation between strength and quantity of matter: yet this opinion is falsified at every step through nature, and nowhere more than in the present case. The feather weighs but a few grains; yet it is as elastic as many a metal spring of the same bulk, and a hundred times the quantity of matter; and far more tenacious against transverse fracture and direct disruption than nine-tenths of those. And this is independent of the

mechanical advantage arising from the tubular form, which only aids the strength against flexion or transverse force ; while therefore, in no other part can the texture alone be the cause. But it was necessary that a feather should combine strength and lightness ; this last demanded a small quantity of matter, and that power which can do whatever it wills, even against probability, has given extreme strength to that which is almost nothing. A mechanic might, with great toil, construct something like a feather : and were he desired to make it as strong and elastic as possible, he would fabricate it from steel ; yet not even from that tenacious and elastic substance, could he produce the hairs, or even the lamellæ ; while, with a hundred times the weight, he would not possess half the strength.

It is from an even more unintelligible modification of this common animal matter, that the Creator has produced all those harder parts of animals, the minuteness of which at length eludes our senses. It is almost sufficient to allude to the several instruments or tools of the insects, by which they saw, or bore, or gnaw, the hardest woods : penetrating even lead, and, in the case of the Pholades, in another tribe, stone. Yet this instrument, be it whatever it may, is formed of a material which can be but horn or quill, as we know by examination and analysis, as of this also are constructed their strong limbs and hard coverings. The sting of a Bee is so small that we can scarcely discern it ; yet it is a tube containing two barbed spears, so strong, that it is difficult to extract them from the skin. The proboscis of a Midge belongs to an animal not so large as the eye of the Bee, while it is also a tube ; so that, utterly invisible as it is, the quantity of matter which it con-

tains must be incredibly minute. But it penetrates the skin, as those of the Coccus and the Aphis, not less minute, perforate the barks of trees; while that of the Asilus will penetrate the hard wing of the Lady-bird.

In what possible manner are such strength, hardness, and sharpness, given to an instrument so minute? I need not say that we cannot give that size to gold or steel; while, long before this, the strength of even the latter metal is gone. No one can imagine a tube of steel no longer than the sting of a Bee, scarcely even such a needle. Gold is more feeble than the weakest membrane, long before it arrives at the thinness of the larger of these instruments; and yet that is not the hundredth or the thousandth part of the tenuity which we find in this simple animal material, quill or horn, or whatever, resembling those, it is. Its continuity cannot be preserved under such reduction, except by the aid of a thicker substratum of some metal; and what it is then in point of strength, we all know. Though, possibly, it cannot be tried, we are sure that the sting of a Bee would bear a greater weight than a gold wire of ten times the size. Of the surface or workmanship I need not speak; to imitate even the former, as we find it in these animal materials, by any labour on any metal, is known to be impossible. It is still more remarkable, that no approximation to those instruments can be made, in even those which appear to be the same materials: since, as far as the microscope has shown, the interior textures are similar, as the chemical composition is the same. Horn, quill, whalebone, ivory, or bone, no mechanic can reduce them to the largest of the dimensions found in those tools and parts; and

they cease to possess any strength long before that size has been attained. This resembles magic or miracles, more than anything in the order of nature: and had this statement been made to a workman ignorant of such mechanisms, he would have fearlessly decided that they were impossible. My reader himself may doubt: but he can convince himself whenever he pleases, if he has hitherto forgotten to inquire and think.

It is unnecessary for the present purpose, to do more than to class all the materials of these structures into hard and soft. In a large animal, it is familiar that the latter are very feeble textures; and membrane will most conveniently represent the whole: as we know that the several other soft parts differ but little from this, in composition or in strength. But though the reader assumed the suspensory ligament in the neck of an Ox as the fundamental soft material, it would make no difference on the total conclusion. I do not ask whether a mechanic could cut a tube out of such a material, even as small as a needle, but whether such a tube can be conceived to be possessed of any strength, supposing that it were made. A solid fibre of membrane, of that size, would be without tenacity. Yet what is that size to those which exist, not even as simple tubes, but formed of separate coats, like the arteries of large animals? And what is the tenacity of a membrane much thinner than the thinnest cellular texture, or of a tendon much more slender than the least conceivable fibre, when both of these, and the former as a ligament, bear all that strain through which the muscles of a Beetle will force the animal's way against the pressure of a strong hand? But this will suffice at present respecting those two classes of materials: the

nature of the Power which gave them their strength will continue to appear more strikingly, in the following exhaustive sketch of the minuteness of organized animal structures. And it is now more clearly seen, that minuteness is not the matter of indifference, which the careless metaphysical assertion that I have already quoted holds out. It is not indifferent as it regards material ; nor is it even such as it relates to space ; for though the same science, under the garb of mathematics, may say that matter, or space, is infinitely divisible, no one can believe that matter, especially of this compound nature, is capable of infinite division ; far more, susceptible of continuous division with as continuous an accession of strength.

It is usual to give very feeble examples of the multiplicity and minuteness of the parts of animals, in naming the numerous hard pieces and muscles and tracheæ of the Maybug, the twenty thousand bones of an *Enerinus*, the *Cossus*, with its four thousand and sixty-one muscles (that I may quote this accuracy rightly), and so forth. There is matter of far other interest than this, and far otherwise bearing on that purpose, which these naturalists have overlooked. It is indifferent what insect I select for that analysis which such dissections can never give : for that dissection which is performed by the mind, not the knife, as the result of reasoning from analogy and from necessity ; a mode of dissection without which this chapter could not have been written.

Let it be a Gnat ; and it is indifferent what size the reader may choose. But he must commence by forming a precise idea of the entire anatomy ; and this he can do by examining a large analogous structure, such as a

Lobster, for example. The visible parts of this I need not describe : but he must also recollect that it contains what he cannot see, arteries, veins, nerves, and lymphatics ; while, would he know what these are, how numerous, how minutely ramified, how intricate, he may consult the usual anatomical preparations of the larger animals. Having mastered this, let him imagine it all reduced in size till it occupies the dimensions of his Gnat. The tubes for the limbs, and the workmanship of the joints with their ligaments, are here equal in accuracy to the corresponding parts in the Lobster : but of what thickness can these hard portions be, how can the projecting minute parts exist at all, the joints give insertions to the ligaments, or to the tendons, or how is it, as I just said, that they are not destroyed by that powerful action of the muscles which I also noticed ? Or why is not the invisible tendon, being a soft fibre, and not a hard material, broken by the force exerted in a Cockchafer, a Beetle, or even in an Ant. Naturalists seem to have forgotten this ; but my reader must not. The ligaments are not so thick, by a hundred times, as that membrane, goldbeater's skin, which they most resemble : yet they withstand a force that would tear this like a spider's web.

What also is the size of the muscles which move those limbs ? There are two within each tube of the leg : in the pincer joints, existing in Acari at least sufficiently small, they are doubtless compound ones, as in the Lobster ; as they must then consist of many fibres. These fibres must be indeed minute ; yet it is nothing, when we are sure that they must be supplied by nerves and arteries, and that this incomprehensible little machine must also contain veins and lymphatics.

It is in vain to say that nothing of all this can be demonstrated. It is proved without that which is termed such by anatomy : it is the negative demonstration of mathematics ; for without all this, life, action, growth, and repair, could not be carried on : the parts could not even have been formed, as I have already fully shown. What can be the sizes of the fifty or a hundred tubes contained within the already incredible tube of this leg ; what are their several coats, the valves of the veins and lymphatics, the tubular membranes that enclose the nerves ; and how do those vessels circulate fluids, when no power of ours can force one through a tube far larger ? Or, if once formed, how do they even hold together, when constructed of such materials ?

There are many insects smaller than a Gnat, whose antennæ are constructed on the same principle as that of the Lobster ; it is for the reader to conceive all the rings, and ligaments, and interior muscles of that organ, reduced to a dimension which he can barely discern. There are many whose whole eye is not larger than a single lens in that of a Dragon-fly ; yet each of them containing many hundred such lenses, each with its blood-vessels, retina, and nerve, were there no more. To note the nerves alone, we know that, in the larger animals, this is the feeblest texture in the body, and that the real nerve has a membranous covering. What then can be the thickness or the strength of three or four hundred of such tubes, enclosing nervous fibres, within the diameter of a pin ; how is there room for them, or room for the nervous matter in the tube ? It should be at least a close crowd ; but the Dragon-fly's eye shows that these nerves do not occupy

more than a small proportion of the whole space : as it is the only large object of reference for this organ.

We are well acquainted with the interior anatomy of insects : and, seeing the larger parts, can safely infer the rest. There are an œsophagus, a stomach, and intestines ; an artery, which, being a substitute for a heart, must have muscular fibres and nerves, and even its own nutrient blood-vessels and absorbents ; and two large nerves, whence branches ramify to the eye, and thence also, by inference, to the whole body. There are windpipes opening at the sides of the animal, and, as is believed, ramifying over the whole body, to serve the purpose of lungs ; and eighty of these have been counted in the Cossus ; though whether this were taken as the standard for all, or not, is indifferent. There are also the ovaries, which are complicated tubes ; and, within these, a large collection of eggs, each being a shell, with at least a fluid and a germ within, are occasionally produced. I need scarcely ask again, where is the space for all these organs, what can be the dimensions of their membranes, how can the soft material be reduced so thin without losing its tenacity ? This is but little out of all that must be. The tracheæ must be permanently open tubes, or they could not transmit air ; they must be of some hard material, or else strengthened by rings, like those of the larger animals. There must be arteries, branching from the main vessel ; else, why is it there, or how are all the nerves supplied, or the muscles put into action, or the body nourished : how was it even produced upwards from the germ ? For every artery too there is a vein, or the blood could not return in its circle ; there must be lacteal absorbents at least, or new blood could not be

formed, and the animal need not have eaten ; and there must be all the other absorbents, or how else is the fat of the insect taken up under the privation of food, as it is notably in the Spider. And how can there be an artery without its muscular fibres, or an absorbent without valves ?

Naturalists and anatomists have doubted or denied this, because they could not dissect and display it all. They might as well have denied the existence of the ultimate ramifications of the nerves, or of the lymphatic orifices in the human body, because these cannot be detected. How should these things be seen, knowing the little power of the microscope over opaque structures ; or how dissected, when the smallest metallic point that can be made is often larger than the whole body of such an animal ?* This is to limit all existences by the imperfection of man's eye : it is he who denies, equally, that the celestial orbs are extended beyond the range of his own vision, who makes his eye the centre of the universe. In more than this, the eye of reason sees what the corporeal one cannot. It was once denied that the simple Infusoria possessed any organs ; the Monas was termed a living inorganic atom. The intestinal structure at least is now seen : and perhaps the custom will soon be to see more than what exists. But it is painful to have seen the first anatomical authority of this age, him to whom I have already alluded, indulg-

* Since this was written, Carus has proved the circulation in insects ; in many it has been seen and traced, and the vessels have even been dissected. It is indeed often peculiar ; but where its ultimate progress is denied, or very unaccountable peculiarities asserted, the difficulty probably arises from our ignorance, or insufficient observation of what is so small and obscure.

ing in these slovenly views, when he says that the parts of insects are nourished through a system of absorption from the intestines. Were it even so, this must require a structure of absorbent vessels, with another to secrete the nutriment to the parts : while those cannot act without nerves, nor can the nerves be maintained in power without blood-vessels. There is nothing gained in point of simplicity by such an hypothesis : and if used to evade the difficulties which I have pointed out, it only succeeds by forgetting to reflect on the nature of absorption. As I already said, he whom the term absorption satisfies, must suppose the insect structure no other than a sponge ; which that anatomist at least ought not to have done. Of the imaginary cellular structures I spoke before ; while, except under such carelessness of thought as this, I showed that no difficulty was evaded by that hypothesis, though it is for the purpose of avoiding those which I have pointed out, that this, equally, has been proposed.

There are as many distinct chemical processes carried on in a Fly as in an Ox ; the external mechanism is more complicated, and the parts are more numerous, more neat, and more artificial. It requires thousands of arteries and veins to produce and maintain these in the latter ; and is the greater difficulty to be executed by less means, or by no means at all ; as if the insect grew by crystallization, like a spar ? or if there were a cellular texture to produce the eye of a Dragon-fly, or the forty-jointed leg of a Gnat, why such an apparatus of arteries and veins to form those in the quadrupeds ? Nay more, we are sure that the antennæ, that all the parts of a Lobster, are produced and nourished in this manner ; we trace similar constructions in a gradation of size

downwards, until we are stopped by the minuteness of the parts ; while it is at this point that nature must change her whole system of working, in conformity to our deficiency of discernment. If these hypotheses have arisen from bad reasoning in the anatomists who have adopted them, from neglecting analysis, so are they partly the produce of chemical ignorance. Without a chemical secreting organ, no solid or fluid of the insect body could have been produced from a common material, be it nutriment or blood ; and without such an instrument at one precise spot, no one of all its materials could have been deposited at that spot : there could have been no structure, no insect, as surely as there could have been no poison in the Wasp and no wax in the Bee. But I have proved the actual existence of a vascular structure sufficiently minute to admit of blood-vessels on the same principle, in the analysis of the insect eye : and if the tubes which enclose the nerves in an invisible organ of this kind can be formed, so might any others. If also the papilla of a Spider contains a thousand subsidiary nipples, these are the very secreting arterial orifices, in another form, which I have here presumed on ; so that in this too there is no difficulty. The main artery, at least, of a microscopic Cyclops or Monoculus, must exist, though there were no other : the tubular œsophagus of a Monas can be seen : and if there are such vessels as this, there is no reason to deny a vascular circulating system in insects, since those might perhaps serve for the minutest arterial branch in a Beetle or a Gnat. In reality, the problem is executed, the difficulty overcome, to our very sight in the one case ; and it is very bad logic that would maintain it to be impossible in the other.

I already showed that this cellular hypothesis had also been applied to plants ; as the presumed fact was used as an analogy to confirm the same, in the insect structures. I also answered it then ; I trust sufficiently. But the cause, here, has not been merely bad reasoning and ignorance of organic chemistry, which is, in reality, ignorance of physiology, but that hostility which naturalists have perpetually shown against the life of sensibility, and the muscular powers, of the vegetable organizations ; thence taking refuge in mechanical contrivances as incapable of producing these effects, as they are unphilosophical, and false in fact. Yet even to this day is the theory of capillary attraction maintained by those who know that a Vine branch flows when cut, that there are woody and bare stems in some tropical plants, not larger than a crow-quill, which conduct the sap, with force, to distances of forty feet, and who ought at least to know also those laws of capillary attraction with which the merest tyro in natural philosophy is acquainted. But when was any one science ever rightly understood, or correctly treated of, by him who did not know all others ? There is no reason even to grant that the vascular system of insects acts like those of plants or feathers ; since this too has been maintained. There is a heart-artery in a Fly, as there is a heart in an Ox ; the food is first converted into blood, to be placed under the command of that organ, or whence is there blood ? Why also is there a heart, if it is not there to circulate that blood through the whole vascular organization, in the fly as in the ox ? There need not have been a heart, if insects were nourished by absorption from the intestines. It would be a conclusion also against all analogy, that the hear

was not the organ first formed in the germ of an insect : it could not have grown by absorption, when there were no intestines : and why must it be nourished afterwards by a different machinery ? It is unpleasing to be obliged thus to speak of reputed or of great names ; but the logic of naturalists and anatomists is certainly of a nature to excite surprise.

The reader may think that I have dwelt longer than was necessary, on what he may also view as an obscure philosophical dispute. In no case have I discussed such controverted points, except where the great objects of this work demanded it ; nor have I ever censured philosophy or philosophers, but when their dogmas and hypotheses tended to excite doubts respecting the Deity, or His conduct ; while, to defend and explain those, as far as may be, is a paramount duty. The immediate purpose here, was to display His power, in the minuteness of mechanisms ; and it was indispensable to prove that minuteness. But there was more, if it is less obvious. The far greater number of similar hypotheses, in every department of creation, are connected, often indeed unconsciously, but not always, with those ancient systems which referred everything to necessary laws : or they imply a secret wish, as they have often done a declared intention, respecting which I need here say no more, that I may avoid censure, as far as that is possible.

But this minuteness of mechanism has not yet been fully demonstrated : I must proceed still further in this exhaustive analysis. For this purpose, let the reader make himself master of the entire structure of the human body, especially in its minuter vascular and nervous arrangements, by means of anatomical prepara-

tions, so as to possess a perfect and lively idea of the whole. It will require no great effort of imagination to conceive a similar, if it is not the same mechanism, reduced to the scale of a Lobster, and thus successively, to still smaller dimensions. An optical instrument would indeed do this for him : he might cease to see the parts, but the laws of optics would assure him that the most minute were painted even on the retina of his eye, and that a more powerful nerve might see them all, whatever was the scale. To what extent of reduction his imagination might carry him, I know not ; but I presume it would fail, when told that there are microscopic animals, as perfect in all their external parts as the Lobster whence he commenced, and therefore containing the same internal mechanism. These are the minute crustaceous animals described elsewhere : with visible limbs of the same construction, and with far more power compared to their bulks. Every joint, ligament, tendon, and muscle, must be similar, or there could not be the actions which we see ; but what is the shell of this limb, whose inconceivable thinness can still bear the internal forces necessary for those violent and sudden motions ? The animal springs through water many hundred times its own length, with invisible velocity : the Lobster is feeble in the comparison. Let the reader conceive the fibres of the gills, the main artery, the optic nerves ; but let him also reflect on the sizes of those arterial ramifications which produced and nourish everything : as he may think more definitely, if he looks at the hairs with which their antennæ are so often feathered, and recollects that each of these is the produce of a distinct branch. This is a reality, not a tale of wonder : mechanisms like this exist in unaccountable myriads, and are produced daily.

Yet this is not the compulsory boundary of such an analysis. There are animals whose entire body does not exceed the end of an antenna in the former : and if they have not the same vascular system, they have active external organs, demanding muscular fibres and nerves ; as, without the latter, they could not even exist. It is indifferent for the present purpose, whether they have a system of arteries or not : they produce eggs, or young ; and the germs of those must at least possess the generating artery, or an analogous chemical and pattern-making organ. This necessity cannot be evaded : without that, there cannot be a secretion, nor therefore an animal solid, far less an animal. And if other analogous vessels are not required to form the several parts, then might a single chemical vessel or orifice produce an Ox as well as a Monas.

Beyond that animal I cannot extend this analysis : it is exhausted, because this is at least a name that must express the smallest animal which the microscope has seen. Observers have said that a grain of sand is equal in bulk to ten thousand, and Ehrenberg computes that there are five hundred millions in the space of a cubic line : computations like these have little value : it suffices that they express the extreme of minuteness. This animal, or its congeners in appearance and bulk, contain more than one stomach, which we can see : if the general organization resembles that of a Medusa, as is not impossible, the reader knows now how to compute all else. The Vorticella of similar intestinal structure has gills, and the Monas should therefore possess the same. But all this is indifferent, as far as the question of ultimate minuteness is concerned. It produces young ones : the mechanisms of these must be much smaller

than those of the parent : once, those were but germs, and, as such, they must have had each its generating vessels. Of what size was this ? the inconceivable minuteness of the Monas becomes a huge body in the comparison. It is a dimension which, under any other point of view, would be a nothing : and it is the last to which I can conduct the reader : the final term of this analysis. Is there aught beyond it ? possibly not : yet I know not why that Power which was not compelled to stop long before, should stop here.

There are readers however who may more easily conceive this minuteness by means of numbers than by the method which I have been using. The roe of a Cod has been estimated to contain nine millions of eggs. The bird's egg teaches us that there is a vessel in each germ : under any view we must at least allow one to produce each of those points which is to become a living animal, as we are sure, here, that they are separate arteries. We should hesitate to allow but one for the production of the nutritious fluid in the egg of the bird ; but if we thus limit ourselves here, there are already eighteen millions. There is at least one membrane, enclosing the germ ; and one indispensable vessel for it, produces twenty-seven millions. Every egg has its spherical shell : it is the case of the pollen again ; and a mechanic must ask himself whether one vessel could produce a hollow sphere. It is a case in which he knows that magnitude or minuteness can make no difference ; while he may also know that the egg of a bird requires hundreds of vessels to form it. But if I take only one for each, there are thirty-six millions of arteries within the roe of this fish : I should not be wrong if, first doubling this number for the veins, as

must be done, I had estimated the whole at many times seventy millions. Yet contenting myself with this number, there was a time when all these were contained within the space of a quill, or in that small bulk, at least, under which the eggs first become discernible. This may appear incredible: but it must be; for in no other manner could this collection of eggs have been formed. And had I taken the roe of the Sturgeon, estimated at the incredible number of one hundred and fifty thousand millions by *Leuwenhoeck*, it is but to enhance what is already incomprehensible.

If I have thus attempted to set before the reader, in a tangible manner, that demonstration of the power of the Creator which is derived from His minute works, I must again urge it on him not to read these words merely, but to bring the facts before his own eyes and imagination, by even a much more slow and perfect analysis than I could here have ventured on; while I still think that he will thus receive a deeper impression of this attribute, than from almost any facts in the whole circle of creation. It is the conclusion which he draws for himself that is ever the really valuable one.

Yet he must not forget to contemplate the materials also; while these demand some further remarks. It is this which constitutes the essential difficulty, as I originally observed; nor can it be removed by the hacknied phraseology formerly quoted. When we recollect what are the atoms, invisible through even the most powerful microscopes, of which entire organs consist, and when we know that these contain crowds of ramifying tubes conveying fluids, we cannot conceive the possibility of continuity, adhesion, far less of resistance or strength, in these materials and mechanisms.

The softer ones are membrane, muscle, nerve ; and, thus extenuated and mixed with fluids, we should infer that they could form nothing but a mass of inorganic jelly, or that an animal so minute as some of those described, could be no more organized than a fragment of the ordinary cellular membrane. Yet however minute a portion of this he may take, be it far smaller than he can discern, he has seen that there are entire animals made of the same materials, as small, or much smaller, than any point which he can separate ; containing mechanisms not inferior in multiplicity of parts, to the Sheep or Ox whence he may have detached it.

Of this extraordinary tenacity in the hard as in the soft parts of all these small animals, accompanied, in the former, by great hardness, or power of penetration, there can be no question : while it is equally plain that it is a property conferred on them specifically, in these cases, as it does not occur in the same materials higher up in the scale of magnitude. And I doubt not that this tenacity is proportioned to the minuteness of the animal, or that the strength of a membrane or an artery is greater in a Monas than a large Medusa, comparing the same materials, as also that the material of the limb-tube in a microscopic Cyclops is stronger than the similar one in the leg of a Beetle. This cannot but be ; since, without it, such animals could not have existed. The Creator cannot fail to gain His ends, be those what they may : it is for us to inquire of the means which He adopts.

Chemistry has already determined that the elements are the same in all these materials ; and statics prove, that from whatever animal taken, they have, all, corresponding specific gravities. There is that, here,

which chemistry cannot analyze : and there is that also respecting which the long-received theories of natural philosophy are as worthless as they are in far more. I have examined these at some length in a future chapter : but in the present case, it is plain that the density, or weight, of a given body, is no measure of its power of internal attraction, and therefore of its tenacity and hardness, or of those properties generally. The tenacity, or strength, of a muscle is augmented for a temporary purpose, without any increase of specific gravity ; or if there be such, which we cannot ascertain, it must be very trifling, compared to the great augmentation of strength. In the sphincter muscles, this peculiar strength is more permanent ; as it is also dependent on life. In this case, there is a power of corpuscular, or self-attraction, which the Creator has deputed the nerves to communicate when required, because it was necessary to the existence of the animal. But we know not how this is done : it is a mysterious power which He holds in His own hands. It was not less necessary that extraordinary powers of corpuscular attraction should be given to the materials of the smaller animals, and without change of their specific gravities ; as also it was necessarily independent of the will, and has been rendered independent of life. He who gives this power hourly to a muscle, has given it permanently to those materials, and in the exact needful degrees : thus rendering the light feather of a bird stronger than gold, and the invisible sting of the Bee harder than steel. But there is no cause for wonder : He has done the same through a thousand fibres in the vegetable creation ; for there too He had purposes to serve. Thus also do we see an example of that boundless

Power which is never at a loss, and which attains all its ends, in its own ways, even when, to us, it seemed impossible.

The physiological inquiries which the present question has demanded, induce me to add a remark, which, if it does not bear on this specific subject, belongs to the general purpose of this work. They who trust, somewhat questionably, to the microscope, have supposed that they had analyzed the ultimate textures, and have decided that they were globular: they have even said that globules, being ultimate and definite in magnitude, constituted the whole of these, in every animal. If it be so, how then are not the vessels in the smaller ones visible also, and are there not even entire animals far less than one of these visible globules? Or is there, for each size, an ultimate and proportional globule? This self-deception, or hypothesis, might be innocent enough but for its obvious connexion with other microscopic conclusions respecting the inherent vitality of certain globules, not of the seeds of *Confervæ* alone, but of inorganic matter. Those observers should not forget, that there may be other causes than life for the motion of solid particles in a fluid, were they but the internal motion of fluids under changes of heat or evaporation, magnified by the great power of these microscopes; as others might be assigned. But all know that there is no novelty in these speculations; as all know by whom they were first entertained, in modern times at least, and for what purpose they were intended. The mechanisms which I have here described were not produced by the concurrence of atoms, nor did such united atoms confer on themselves unequal powers of self-attraction.

CHAPTER XXX.

ON MUSCLES AND ON MUSCULAR MOTION.

IN the last and in preceding chapters, I have explained the general nature of the animal machine, and, as far as can yet be inferred, the manner in which it is constructed. But were there no more than this, it would remain as inactive as if it were made of brass or iron. The muscular fibre forms the base of the machinery employed to move it: while collections of these constitute those muscles, of which the general distribution was formerly noticed. But in this fibre, the microscope discovers no more than it has done every where else; or at least nothing to the purpose. The ultimate texture is supposed to be globular: but every other one is, or appears to be so, equally; and I need not repeat the childish hypotheses which have so often been produced respecting this and its modes of action. Suffice it, that physiologists have sought in a mechanical structure, what they should have endeavoured to find somewhere else: while if there was an age in philosophy which offered excuses for such purposeless writing, there is none now. Philosophers would be laudably employed did they examine and infer, though they should still fail; but ever ready with imaginary solutions, they are not even innocent; since false causation suspends inquiry. It is of the conduct of the muscular fibre that

I here propose to offer some statements ; as displaying examples of the power of the Deity, very distinct from anything which has preceded. Muscular action is indeed exerted in many other ways than the more obvious one ; but, as far as I can well separate the voluntary and the conspicuous, from the involuntary and the unseen motions, these last may be reserved to the subsequent chapter.

The facts that we know respecting this fibre, are equally limited and simple. It contracts in length when the nerve connected with it is stimulated : it does the same by an action of the animal's will, directed, however, to an end, not to the means ; and in other cases it contracts similarly, without the will, and without injury or stimulus applied to the nerve. But in each case, with an exception to be noticed hereafter, which does not, however, interfere with this conclusion, we know that the impulse comes from the brain, or other nervous centre ; because when the nerve is tied, or separated from that, the fibre ceases to contract. While approximating its extremities, it also becomes denser, or firmer, and more tenacious ; sometimes also becoming conspicuously wrinkled. And by this simple process, every motion in the system, of whatever nature, is produced.

Now, in whatever manner the wrinkling is to be explained, as it has not been, all that we can reduce this fact to, under a general expression, is, that the attraction of cohesion in the fibre is augmented during its action. In the sphincter muscle, noticed in the last chapter, this fact is presented in the simplest form. Being dead, or its nerve separated, it is feeble and easily lacerated : under this additional attraction of cohesion,

transmitted through a nerve, it is a substance of great tenacity. If my former suggestions respecting the tenacity in the soft parts in the minuter animals are correct, the two cases are analogous; but that which is permanent in the one case, is temporary in the other, because both modes of proceeding were required.

It is nearly the same in the straight, and occasionally-acting muscle. A temporary influence is transmitted through a nerve, and, while that continues, the cohesion, or mutual attraction, of the particles of the fibre is increased, and to such a degree as to alter its shape as well as its length. And thus also that muscle, which, if out of action through the separation of its nerve, or from insulation or death, might not have supported a pound weight without laceration, may, under this influence sustain a thousand.

This indeed does not explain much: but it is as much as we know of the attraction of cohesion in any other case. If a fibre of iron be heated, its cohesive attraction is diminished; if cooled, that is increased. In the latter case also, we know that its particles approach, because it becomes shorter, or rather, smaller: and we may say that heat insinuates itself among these, and, by weakening them, diminishes their cohesive attraction. Yet this explains nothing more than the language I have here used respecting the muscular fibre. We are as ignorant of the nature of heat as of that of the nervous power: and if its presence can diminish cohesion and separate parts, why may there not be a power capable of doing the reverse? But we know that there actually is one such power, if not more. Magnetism effects this, if almost as partially as in the case of the muscular fibre: and I might add electricity

if I chose; presuming for the present, that they are as independent as they were formerly considered. And in saying that the nervous power, produced in some manner by animal action, and dirigible by the will or otherwise, increases the cohesive attraction of the muscular fibre, the language is as correct and explanatory as when we say that magnetism augments the cohesion of particles of iron: while equally ignorant of aught but the fact, in both cases, as it is doubtful if we shall ever know more.

I do not call this an explanation of muscular motion, though philosophy is satisfied every day with worse ones on many subjects. But it will be of some use, if, in simplifying our language and preserving some uniformity in our terms, it shall also put aside the hypotheses with which this subject has been encumbered. It will also show us where the limits of our knowledge lie: if metaphysicians had done this on everything else, they would have saved themselves and their readers much trouble. And with this view I repeat, what the very object of this inquiry compels me to enforce, that all which we know of the effects of life on muscles, through the medium of nerves, is, that their attraction of cohesion is augmented, though in a manner very much differing from those which occur in the analogous cases quoted.

It was necessary thus to define muscular action, or to reduce the principle to the rank of the other analogous mysterious ones, that I might be able to speak of the power of the Creator in a manner equally simple, on all these subjects. In the case of gravitation, He has caused the sun and the earth to attract each other; or there is, in His hand, that mysterious power of

gravity by which He rules the great machine of the universe. He has also caused the particles of matter to attract each other ; and that this power is equally in His hand, I have shown in the last chapter ; since it is unequally distributed to the very same substances, under no efficient cause that we can possibly conjecture, but because it was required and as it is needed. And this is the ordinary attraction of cohesion. And lastly, He has also kept in His hands a power of attractive cohesion which He can distribute, in many different degrees, in a temporary manner ; while, in this case, that distribution is confined to a peculiar substance and structure, and through that contrivance which forms the nervous system under life ; appearing to us the efficient cause, though we are as ignorant in this case, as in both the others.

If there is an analogy in the three powers, all are mysteries, and at present all are equally such ; as we can refer to nothing but Him for the prime force. Yet the mystery of muscular motion has appeared to philosophy to be less than the others : and thence perhaps the hypotheses. The nerve is at least entwined with the muscle, and it communicates something, derived in some way from matter. Thus we have that which so often satisfies a vulgar philosophy ; matter, and contact : while in the case of the planetary bodies, as in that of magnetism, the communication, or even the intermediation of a substance, appears to be impossible ; notwithstanding the hypotheses on those subjects of which I need not here inquire. These are cases of a body acting where it is not : in the other, the body is at least acting where it is. But that the total mystery is as great, if not greater, I shall very soon show.

If, on subjects so far beyond our reach, opinions and hypotheses are of no value, they may still be interesting: and there is an interest in the philosophical speculations of a remote antiquity at least, springing out of the age and times themselves. The opinions of the ancient Hindoo philosophy on the subject of muscular motion, coincide with what I have here suggested: suggesting attraction, however, rather as a convenient term for use, or as a sort of algebraical symbol, than an explanation. To the four popular elements, this philosophy adds a fifth: while, whether we knew it or not, its properties resemble those of the æther of Newton. In the Vedas, Aditya, force, or attraction, is the child of the Goddess Aditi, and is the cause of magnetism, electricity, the motion of light, gravitation, sensation, and muscular motion. I may also observe, that this philosophy had proposed long ago, what has recently been brought up as a new hypothesis; namely, that while gravitation caused all the celestial bodies to tend to each other, so did it produce a tendency of the whole to a single point in the universe.

To return to the facts; the Deity has appointed machinery for conveying to a peculiar structure appointed to receive it, some substance or power which increases its cohesive attraction. And He has ordained that it shall be produced by an animal organ, as everything else is, from blood, while it is exhausted by use, and must be replaced, as every other animal production is, through food. That the nervous power is a substance, we do not indeed know, since we have never found such a one, and need pay no attention to the fancies of physiologists on this subject. We infer this, because it is produced by chemistry, from matter, from blood,

as just said, and also because the power of muscles, indicating a greater or less supply of this mysterious substance, is in some way proportioned to the quantity of air breathed; as seems deducible, if not to the extent asserted, from comparing the birds with the fishes and reptiles of imperfect lungs. Still, if electricity and magnetism and light and heat are not matter, as they are not spirit, while we have neither term nor conception as to any third thing in the universe, the nervous power may be of the same incomprehensible nature, yet still possess an intimate connexion with matter, and also be under its power, as those are.

Such is the fundamental display of the power of the Creator in this case, as it constitutes one of the most unintelligible; at least to the philosopher: an ordinary reader will be more struck by the mechanical difficulties analyzed in the last chapter. We are accustomed to view gravity and cohesion both, as matters of course: but if such a reader will ask himself what he would feel, if, by a touch of his hand or the breath of his mouth, he could give to a silk thread the strength of an iron wire, he will acquire a better conception of the power which is displayed in muscular motion. But as many are more apt to feel the force of details than of general views, I will proceed to point out a few of the most remarkable facts under it, as they will represent this mysterious power in a light which must strike every one.

A reader unacquainted with anatomy will be much surprised at being informed of the strength which a muscle may possess; and still more so if he resolves this into an increase of cohesive attraction, as I have here done. The muscle which bends the fore arm is

not very large, and being inserted close to the joint, the lever is against it at the hand. If he lifts but thirty pounds from the elbow, and this lever is taken at but ten inches, he is in reality lifting three hundred-weight: while, as the muscle acts equally on both insertions, it is in reality sustaining a force of six hundred; as it would do practically, could it be slung over a pulley in its state of action. Yet if the nerve were cut, a very few pounds would tear it asunder. An invisible, unassignable influence, directed by his will, he knows not how, has, in a moment, increased the cohesive attraction of a feeble animal compound, in almost the same degree as if it had suddenly converted a rope of cotton into a bar of iron.

If I have put this case in a plain manner, I have not stated all the circumstances of unfavourable position and action which render the strength of muscles far greater than a mere unfavourable leverage would prove it to be. The acute angles at which they sometimes act, unfavourable positions acquired during their action, the passage of a joint, and more, are facts for which the details of anatomy must be consulted. And it has been estimated, rudely enough however, that the visible force is not more than a sixtieth of what is actually exerted. It is indeed fruitless to attempt any estimate of a power which differs so much in different muscles, in different animals, and often in the same animal, or muscle, under different circumstances. The strength of the pectoral muscles of many birds, and of those of the thigh of an ostrich, is far greater than what occurs in the human body, or, I believe, in any quadruped. In insects, it is absolutely incredible, when we compare the size of the muscle to the force

exerted. I formerly noticed the power of a Cockchafer; but there are Beetles far stronger than this. Now in these, the size of the muscles which move the legs so as to lift a heavy weight, is not equal to a fine sewing thread, while the action is as disadvantageous as in all other cases: yet if such a Beetle can force its way through the closed human hand, the power of a few of these fibres is equal to that of all the flexors of the fingers, which exceed them in size many thousand times. And if the whole of the force exerted were to be calculated, as any one may easily do, it would appear still more incredible: while, when I repeat that this force, in each minute muscle, is the measure of the cohesive attraction which it has received through the nerve, I am far within bounds when I say that this soft, and, on other occasions, tender substance, has, at that moment, become far stronger than the most tenacious metals of the same dimensions. Had the fact been stated of any other thing, that such a thread could assume in an instant the strength of iron, it would not have been believed: but because it is familiar muscular action, we forget to note that, which, in any other case, would be termed a miracle.

And might not He who thus adds, in a moment, ten thousand fold to the strength of cohesive attraction, equally, in an instant, add to the force of gravitation? cause the moon, if He so chose, to descend to the earth, or confound the whole planetary system with the sun? He might unquestionably do all this, and more, because He is omnipotent: and we can here see, that if He should do such a thing, it would not be that violent inconsistency with the laws of nature, or the hypothetical miracle, which we are so ready to suppose. Or, were

He to give to a rope of sand the strength of a chain, it would not in reality be a greater miracle than muscular action, though it might appear so to us, because we have never witnessed what fable has invented of supernatural powers. The process would be essentially similar, and the effect the same: but if, in the one case, He has established deputed means, because that was needful, surely His will might equally effect what it desired, in the other, without any intermediate ones, or any that we could discover.

It is not my business to discuss the great question of miracles, in this place, or this work; but the present subject justifies me in making one remark on a celebrated objection that has been produced against their possibility, or probability. It is said that they are incredible, because they are out of, or contrary to, the order of nature. The moral answer is easier than it has commonly been represented: because the objector should first prove that the Peripatetic system is true, and that God takes no present concern in that which He established at the beginning. But I am not now about to answer the hypothesis of general laws again. The present answer is, that while the phraseology, "order of nature," is sufficiently loose, the objector should at least have proved that he was thoroughly acquainted with the laws of nature. If the assertion means, simply, that the event in question never had occurred before, he ought to show that he knew every thing which had happened; or if, that it was opposed to the demonstrated laws, he should prove that he knew all those, and all the modes in which they might act. Even if we knew all the laws of nature, it would be assuming a great deal, to say that He who appointed them might

not cause them to act in an unusual manner, or even that they might not act so, in consistence with a pre-established system; the particular event being unusual, only because it had not been known before. And if it can be shown that any of the miracles to which objections have been made, were produced in consistency with the acknowledged laws of nature, then is the argument especially worthless; since it is that of ignorance, assuming to know what it did not; whatever more it may be.

To show how easy it is to deny a miracle, under the belief of knowing every fact in nature, or of knowing the laws of nature so well as to be confident that the asserted event could not have happened under them, I may refer to a case which I noticed in a very different work long ago. The simple occurrence was, that iron which had lain under the sea for more than a century, was so hot on being brought up, that it could not be touched. Mr. Hume's argument, resting on the comparative probability of the fact, and of the veracity of the evidence, had here its full triumph for fifty years. Yet when the cause was then ascertained, in the course of my researches, the fact proved to be in the "order of nature," and to appertain to the laws of nature, and to Chemistry.

And if a miracle is produced by modifying or extending some law of nature, there can, on the same grounds, be no argument against its production. The case just supposed, of a rope of sand rendered as strong as a chain, would, in one of the senses of the opposing argument, be a doubtful miracle, because such an event had never before been known: but it would not be such in the fuller sense, because it would be only the putting in

force of a general law, applied to other cases, if not to that exact one; to the feeble materials of insects, for example, and to muscles. And to quote a recorded miracle, particularly applicable to the subject under review, there was nothing to be created, nor any law of nature to be contravened, in the case of Samson's unusual strength: while a simple calculation will show, that had his muscles but received, at the necessary moment, that power which is given at every instant to those of a beetle, he could have effected what he is recorded to have done. And that would surely be a small deviation from the order of nature, which would cause one animal to perform what is for ever executed by millions.

If I must not pursue this controversial matter, it requires little knowledge to see, that there are but very few miracles that are inconsistent with those physical laws which we suppose ourselves to know. The healing of diseases is especially within the order of those; since it is the work of chemistry set in motion by the nervous system, as that system is plainly under the command of some power beyond that of its possessor: and why not, then, of Him who made it? And though the restoration of the dead to life is a miracle in the usual sense, as it is a religious miracle, it is a fact as much in the order of nature, as that which occurs when He who appointed that order gives active life to the seed which had remained dormant for a century, or to the dried *Vorticella* which has been blown about for months, an insensible atom among the dust of the ground. But I must not pass my limits.

If I formerly remarked, that under the necessities of symmetry, and convenience, and velocity of action, much muscular power was sacrificed, it is now plain that the

saving of power was no object ; since it might have been conferred on even a human muscle, to the extent of that in the leg of a beetle, had such a compensation of disadvantages been required. And we can suppose that this might have been done by increasing the number or bulk of its nerves, though anatomists have not yet carried their researches so far.

The precision in the action of muscles is another of those wonderful and inexplicable facts, which we must again refer to the mysterious laws of Him who communicated to them their power. Were it not known to be a fact, it would be incredible : and could I succeed in stating the case as that of some machine, so as to keep the real subject out of sight, it would be pronounced impossible. If the most familiar cases afford the best illustration, no description can compensate for a personal examination ; while a technical detail of the parts in action would only confuse the reader.

It is familiar that a performer on the violin will execute the notes on the upper part of his finger-board, with the same unerring precision as those where the difficulty is far less ; but few have reflected on the complication and the accurate action of the machinery with which this is for ever done, and even with scarcely an assignable volition on the part of the agent himself. The point where the string must firmly touch the board, is so precisely fixed, that less than the breadth of a hair in error would produce that false note which never occurs, even where such place, though apparently the same, must differ, in two cases, by some equally minute part, because of enharmonic differences in different scales. Yet the finger which presses the string is thick and soft ; and if both that pressure, and a peculiar obliquity of position,

were not as constant as all else, the necessary point could not be found. Yet that one point, and fifty more, are found, at once, with the utmost rapidity, and in all kinds of irregular successions ; as if a single lever, moved in the simplest possible manner by machinery, had done the whole ; though the complicated actions of every muscle in the hand and the arm, and of many also in the neck and the trunk, are required to determine every motion of a finger to its proper place. At every note also, the whole of these are put into new actions : while if any one of this great number should fail to act as it ought, the desired effect will not be produced. If this occurrence of constant and accurate successions and combinations is as wonderful as aught else in the history of muscular action, I must now content myself with urging the mere precision of that ; which is such, that if a hair's breadth of error would produce a false note, the hundredth part of that in the action of a muscle would have the same effect, in consequence of their relations to the levers in motion and to the fingers.

If the question should now be put to a mechanic, whether he could hope to construct a connected set of levers, like the hand and arm, moved by the same contrivance, and capable of producing the same effects, even if he had the full power of shortening those strings, and all the time that he desired to do it in, he would not only pronounce it impossible, but that he could not do it by the nicest combinations of wheelwork acting on levers. But the common act of writing will demonstrate the same precision. The quantity of the deviation, in the inclination or other peculiarities of the strokes, in a word which is formed by one hand, from that which occurs in the same word produced by

another, is scarcely to be measured, in comparing handwritings. Yet each man's is his own, and differs from all others. The action of the muscles in each must therefore differ; and, in many of those muscles, far less than the shapes of the letters, for the same reasons as before: yet, in every man, if these incredibly minute differences of action were not constant, then could there be no distinctive character in handwriting.

But the strongest proof of the accuracy of action which muscles can acquire by use, is found in the cases of archery and slinging; above all, in the latter. In the first, the exact elevation of the projectile is determined in a manner of which we are not properly conscious, as is also the force adapted to that elevation: and it requires little reflection to see, that under all the complicated actions of so many muscles, the problem to be solved is so intricate, that no mathematician could ever hope to assign what was necessary to produce a result, which is as certain as it is rapidly effected, without any calculation. In the case of the sling, the projectile is detached at a certain point of revolution in a circle, the plane of which is as unknown as the point of detachment: yet if both these did not bear a steady relation to the velocity of revolution, and to the elevation and distance of the object, the stone would miss that mark which it does not fail to strike. Of all those things the slinger is utterly ignorant; and though he were the most profound mathematician, he could not determine what his conduct should be: yet the muscles have learned to do it, and they execute what the willing and thinking being could not effect.

But the precision of muscular action becomes much

more wonderful, when we refer to the cause, and ask in what manner a definite quantity of cohesive attraction, and also various definite and unequal quantities in succession, can be transmitted through a nerve ; while this too is done by an act of the will, yet of will, merely knowing what it desires, not what it performs. If a man could, by a volition and a touch, give to a silk thread the strength of timber, lead, gold, steel, and so on, and change all these as often and as quickly as he pleased, it would scarcely be more wonderful ; since the real case is as inexplicable as the imaginary one would be, did it occur. Cohesive attraction is measured out in different proportions, and in an instant, by the mere desire to gain an end. The being who conferred this power, surely did nothing more wonderful when He appointed the laws for the celestial orbs.

But He has done even more than this, in conferring the constancy and the facility with the precision : that other great mysterious law, through which man becomes almost a machine, acted upon by a foreign power, not by his own. And with this I must unite the association of muscular actions : or that concatenation which, in some cases before practice, and in others, only after it, causes many muscles to act in a certain order of succession, or simultaneously. Many at least of my readers know, that these have been favourite subjects of discussion with metaphysicians ; apparently for the usual reasons, that what is unknown admits of an interminable phraseology, while real knowledge can be condensed in a few words. And there are some who surely know, that out of this mist of language, not a single ray of light has ever proceeded : as there are a few who can discern whence that mist arose, and also

to what it tends ; though all who have thus written did not see the conclusions that would be drawn from it. But as these speculations bear equally on the subject of the following chapter, I must defer the little that I intend to say respecting them.

The constancy of action to which I have alluded, is one of the most important laws by which the animal machine is ruled. It is easy to accumulate words ; but we can form no conception of the manner in which this end, and the facility of performance connected with it, are attained : while it is here, as we quit physics and draw near to mind, that we must bend to unknown power, in acknowledging our ignorance. All that we really know on this subject, as regards the muscles of voluntary action, is this. It at first required a distinct effort of will, to produce even two motions of the same kind in succession ; it required much thought, to produce some given action in a particular manner ; and it required much more, to produce a great many such, in fixed succession : while, in every case, if there was thought required, so time was wasted, and much effort applied : the results being imperfection, tediousness, and fatigue. But, through repetition, the successive actions are performed without a sensible effort of the will ; they become precise and certain ; that which used to be slow is done quickly, and what required great strength and produced fatigue, is now performed with little effort and as little exhaustion. In time, the agent himself cannot discover that he performs one in a hundred of those efforts of distinct volition which he did before : he wills an end which used to be attained through many intermediate acts of willing ; and that end is gained, without his even per-

ceiving the several steps. He becomes the automaton that I have called him ; another power than his own seems to have taken charge of his voluntary actions, as it originally did of those of his heart ; or he is in the condition at least of a machine, which once placed under the power of a spring or a weight by himself, continues to perform a certain train of motions.

The cases by which this might be illustrated are as endless as they are familiar ; but those already selected to show the precision of muscular action will equally serve the present purpose, since, in practice, these several things are inseparable. How perfect a demonstration of Divine wisdom the whole affords, will appear on a very slight reflection, though too often contemplated under its evil effects, by all of us ; too apt to overlook benefits, while ever ready to note evils.

Man, it has often been said, is a "bundle of habits." Those are words which pass over the ear, unnoticed. we must fix our attention on the consequences, before we can appreciate the wisdom of the law. Confining myself to his muscular motions at present, it is the law of habit which makes man what he is : without it he would be an infant on every day of his life ; for ever learning, and for ever to learn. He is dexterous, a mechanic, a balancer, or a musician, because of habit : nay, he walks but through the same law, as, without it, he of thirty would totter like the infant of a few months. But for the law of habit indeed, the whole world would be ever in its infancy ; since little could at any time be done, when every one's attention would be so occupied in thinking how to do it, that the time necessary for determining would have left little for acting.

The law of habit is education : it is nearly man

himself; since it not only rules his mind as well as his body, but aids to form that mind: ruling both his intellectual and moral faculties, the inclinations and actions of his mind, like the movements of his muscles. And thus also it is with respect to his opinions, or rather prejudices; of what we blame, and forget to praise; blaming, perhaps chiefly, because we apply an odious term to a law of action which produces good as well as mischievous effects. Bad habits: the phrase is common. while it is as common to forget the adjective and to censure the substantive term; forgetting also, that but for those, the man himself need not have been, since he would have been useless. Prejudices: the word has ever a harsh meaning; but a man's prejudices are his rules of action, as they are his necessary ones: since he must often act before he can balance, as the great mass must ever act thus, because they cannot balance, or reason. To deprive man's mind of his prejudices, would be as if we deprived his body of its habits: in each case, he is nothing; he would be a child for ever. Let us study to acquire good habits and good prejudices: but in the mean time let us revere the wisdom that made man this kind of partial machine, knowing that this was necessary for his welfare.

But it would be beyond my bounds to pursue this subject as it deserves: it is enough that I enter on the regions of metaphysics when it is indispensable to the purposes here in view. I must proceed to notice some facts in muscular action, where the same muscles are occasionally under the power of the will, while also acting without, or against it, and even without the knowledge of the possessor and apparent agent. The

term mixed has been applied to those, but it is insufficient to distinguish all the cases; while, for the general reader, I need not here attempt a technical classification which belongs to physiology. Suffice it to note the chief cases, and the reasonings as to the wisdom of the Deity, to which they give rise: while it will be seen that the selected facts gradually lead us to the subject of the next chapter, where every motion is unconscious as it is involuntary; as the very movements themselves are rather inferred than witnessed.

The numerous muscles required for breathing demand the first place. Whether, like the heart, these muscles have been originally placed under a law of alternating action in some measure, or whether they are merely excited to act by that sense of a want which is a stimulus to the lungs in the first place, and to the mental ruler of action afterwards, I need not here ask; the fact that now interests us is that the same muscles, acting in the same train, are also placed under the limited command of the will; so that there is the consciousness of effort in these cases, while there is none under their ordinary motions. The law is peculiar; and the contrivances may be complex, for aught we know: but physiology has not yet proved that the last hypothesis it has produced on this subject is the explanation. But it is the utility, and therefore the power and wisdom that appointed it, which form our concern in this place.

Animals at large were to have no power over their own lives: if man possesses this, it is the result of his peculiar intelligence and free-will. But not even to him has there been granted a power over his vital actions, by a mere effort of will controlling them: all

the muscles essential to those have been taken out of his hands, as far at least as he is a conscious and willing being. The operations of nutrition, secretion, digestion, and circulation, proceed equally without his will and his knowledge: he is a perfect machine, thus far, in the hands of his Creator, or under a governing power which is not himself. And thence, equally, has his power over respiration been limited: he may suspend, but he cannot command it to cease; the unknown and unfelt ruler of the body resumes its office, and his will must submit to a higher power, to the command of his Creator. But the power of partial suspension has been granted, because it was necessary: as in the common case of listening, or of steadying the body under nice actions. Thus, it was also required that the animal, of whatever nature, should have the occasional power of inhaling a larger quantity of air than usual, and further, of expiring it with unusual force, for reasons and uses which are well known. Hence has the voluntary power been given; yet under the restrictions which I have noticed, admitting of every use, but preventing all abuse. Nor must I fail to notice another act of wisdom, in rendering the ordinary actions of those muscles involuntary. Had that been imposed on the will, the necessary attention would have been enormous; we could scarcely have attended to anything else: while even now, he who chooses to make the attempt, as he can, will soon find the fatigue, as well as the attention, intolerable.

Since others have dwelt much on the action of swallowing, I must also notice it, though it offers little other interest than do the associations of the voluntary muscles in general. If it is said, that although we will

to swallow, the action of all the engaged muscles is involuntary, this is equally true of every other train of muscles in the body. The only difference of any value for the present purpose, is, that the association of this train has been given from the birth, whereas most others must grow out of practice, as they become easy from habit. The wisdom is obvious; because these, and the motions needed for sucking, were indispensable to the infant animal: but while this arrangement is not everywhere limited to swallowing, so is the foresight of the Creator marked, in giving those equally early powers to every train of muscles necessary for the new-born animal; as is familiar in the Colt which must follow its dam, and the Chicken which must seek its own food: not to name endless instances more.

On similar general principles, but under a different arrangement, the unknown ruler knows how to act under sensations which are felt by us, and also under impressions which we can scarcely be said to feel, by putting into motion, without our will, muscles which have but a remote connexion with the part suffering or feeling; while equally leaving us a voluntary power over the same trains. The case of coughing from disease or foreign matters in the lungs, is of this nature; as the remedy is one which our own intelligence also applies, when we chance to know of the evil. It is still more worthy of admiration here, though the fact rather belongs to the following and a future chapter, that this great organ should have been provided with a special sensitive defence, apparently because sensation would have been as injurious here, as in the heart and the brain; while, in each of these two cases, there was sufficient protection without it. The larynx is the

guard to a sleeping army: and a sensation threatening injury to the lungs, excites the muscles, both through involuntary and voluntary action, in prevention or remedy of the evil.

Under impressions which we can scarcely be said to feel, or do not attend to from their slightness, there are the same proceedings under similar contrivance and wisdom: though the voluntary actions are scarcely concerned in these cases, or are at least such, that we cannot often decide what their nature is. Such is winking the eye from the sight of probable injury or from touching the eyelashes: while in each of these cases the eyelids perform the office which the larynx does for the lungs. In an analogous case in certain animals, we cannot discover whether the similar actions are voluntary or involuntary, as they may include both: while this little-noticed contrivance demands admiration among the mechanisms of animals, from its simplicity and efficacy. The long bristles on the eyebrows of cats, and many more, are a remote warning to the eye, because eyelashes might have been insufficient; and similarly, those on the cheeks serve as measures for narrow passages, warning the animal against a dangerous entanglement.

I have thus gradually arrived at the cases where, while all the actions are involuntary, yet in muscles of sufficient conspicuity, no impression is felt; the sensation, whatever it be, inducing the unknown ruler to perform the necessary actions, without any participation on our own part, in any manner, or any knowledge of the facts. And I introduce them here, because they complete this gradation; though rigidly belonging to the following chapter, where I have placed the case of the heart, being similar, for the same purpose.

The stomach and its dependencies perform very complicated duties, with perfect accuracy; executing also some unusual or incidental ones, in remedy of defects or accidents: and all these being directed by some intelligence, because, had we the requisite knowledge and command, we should do the same: while these have not been given us, for the reasons assigned in the case of the lungs, and elsewhere. In this instance, the machine is purely automatic, as far as we are concerned; yet through the sensation and consequent action of some unfelt and unknown agent, being the equal director of the voluntary muscles, under the will to gain an end. It cannot be maintained that a train of necessary actions has been laid here, as in the case of the heart, acting alternately without stimulus, and before such impressions had ever been received; while it is equally idle to speak of those "sympathies" and "associations" of which I shall inquire hereafter. In the former case, none but the natural actions could exist, and there could be no remedial powers to meet contingencies; while, of the latter, I shall have ample occasion to speak in the next chapter. Not to quote disagreeable medical facts, in illustration of this kind of impression and action, I may note the case of the Ox, where four stomachs are employed, while the grass enters into one, and the cud into another, without error, as without voluntary power. It is easy to conceive how the orifice of the second should close against the rude vegetable, but not why that of the first should refuse a passage downwards to a much softer material, which it also once transmitted upwards.

I may conclude with a few remarks, which I could not well have made before, stating a case of action, purely and always involuntary, preceded by impressions

that we do not feel, yet known by an intelligent power, which acts rightly in consequence of them.

We call the ordinary process of breathing involuntary ; yet as far as the action of the muscles is concerned, we are in danger of deceiving ourselves by the double application of one term. Some other power or will, directs them in that case ; but it is no otherwise when we will to breathe, for we can neither direct nor control one of them. The action of swallowing is considered voluntary : it would be more correct language to say that there was an intention, or a will to swallow. There is no more command over the muscles here, than in the case of respiration. We might as well say that we commanded the heart to move. The same power which moves the heart, puts forty muscles used for swallowing into due and very complicated action. This was arranged for us before we were born, before thought or consciousness : and had we been voluntary agents in this case, commanding our own muscles, it is doubtful if we should ever have learned to swallow. There is no essential difference as we proceed, even where the motions are those which we have acquired by practice. We desire to pick up a pin ; and we put our finger on it, without knowing how : though there may be two, or ten, or fifty muscles brought into action, and into very complicated and precise actions, while we know nothing of their motions, or of their places, or even their existence. It is the same for a thousand things : the actions, and even the numbers of the muscles, differ each time ; yet the object is always attained. Mechanics, under the bare statement of the fact, would say this was impossible. It is plain therefore, that man, (and all animals equally, of course,) does not command any of his muscles ; they

are all as independent of him as is the action of his heart. And he knows no more of their places, uses, or numbers, than the quadruped ; he does not even know, till he is informed of it, that he possesses such organs of motion, or what it is that moves his limbs. The labourer who turns the winch of a dividing engine has not graduated the limb of the quadrant : and man, even in walking, is equally ignorant.

But if the unknown agent performs what the conscious one desires, the faculty, even to that mysterious portion of ourselves, seems to grow but by exertion and use. It is capable of education, as the conscious entity is : and the more it is educated, the less necessary does the will, or the action, of the other become. The musician has at length but a very general intention to produce an end ; and when he can play even during sleep, where is his will ? The other portion of his mysterious being has learned to do what was once his own duty.

All this is surely as wonderful as anything in the whole circle of nature. And who or what is this agent, when it is not the conscious man ? It is the mind still ; but it is some portion of it from which consciousness of knowledge has been separated, while knowledge remains, and is even capable of increase : just as sensation, or consciousness of impression on the same portion, has been separated in the sentient part of the system. If this is of the most unintelligible exertions of the Power of God, so is it a result of His Wisdom ; for I have already shown, and shall have occasion to show again hereafter, that without it, even man, the especially intelligent, could not have conducted himself. The Creator has given to all animals the power to gain their ends, but no more : beyond this, all are subjected

to another power, and that power is wise, or knowing, even where the conscious being is utterly ignorant, and can never be otherwise: for it knows how to conduct the Oyster and the Medusa, and even the almost vegetable Hydra. Does it not equally conduct the very plant itself; or is it indeed God that is present and acting, as the thoughtful being, there, and everywhere else? I shall have occasion to speak of this again.

Man then is a machine. It has been said that the inferior animals were such. That is true: but it is equally true of both. The body is a machine, in all, given for the use of the mind: but which the mind knows not how to govern in either case. The mind expresses its wants by willing, and the machine is wrought by another hand. If even man were not provided with such an agent, he must hire an artist to work it for him; and if he could find one, he would express his wants, and his artist would supply them. As it is, he does no more: and the present artist, of whom his ignorance knows not, or whom his vanity would forget, is ever at work for him, even when he sleeps.

If I have just observed that the system was wise, I must briefly repeat what I said before, in these general remarks. Had man been occupied in working the whole of his machine, he could have done nothing else: he could scarcely even have done that, for want of time, had he possessed all the requisite knowledge. And that knowledge he could scarcely have possessed in his infancy, except under implanted instincts. The case of other animals is analogous, if not identical. No superfluous labour has been forced on either: the machine was given for the sake of the mind; and it is sufficient that the mind desires: while if there is labour, as labour

is necessary, for many reasons, it is far less than it might have been, had not the Great artist wrought the machinery by His own power, under the mysterious arrangements in question. And thus has He empowered the animal mind to work, (be it said with reverence,) like Himself, through mere volition; though, unlike Him, through corporeal organs.

One remark, of a moral nature, remains. If it be asked why man is not as perfect at first, in the voluntary as in the involuntary motions, or why not as speedily perfect as the lower animals, the answer to the last is, that they have fewer duties; and, to the first, that he was meant for a progressive and improving being, while the very labour of acquisition forms his mind. That it was not designed for all men to be equally perfect in everything, is also obvious from other parts of his constitution; while the necessity of acquisition forms part of this provision, as the result becomes the reward of the exertion; being an example under the divine justice. The reverse appointment would also have infringed on that which distinguishes him from the other animals, his great free-will: he would have been the creature of rigid instinct, or destiny. But as it was useful, not less than just, that he should acquire the means of doing perfectly, or readily, that to which his necessities, or choice, directed him, the power of acquiring habits of action as perfect as those given to the involuntary muscles, has been granted him. In this manner is man rendered efficient, and within certain limits, perfectible: but thus also is his will left free; as the industry and thought which are so necessary to his welfare are excited: excited and rewarded at once.

CHAPTER XXXI.

ON THE INVOLUNTARY AND UNCONSCIOUS MUSCULAR ACTIONS, AND ON CERTAIN MODES OF SENSATION.

IN the last chapter I examined the easier questions relating to muscular action ; easier at least, inasmuch as the facts are more obvious ; though it was impossible entirely to separate that inquiry from the present one, on account of the gradation into the subject before us, which I then noticed. The minute muscular actions, unattended by consciousness, or knowledge, as by volition, form the chief subject here ; though similar muscles, of great conspicuity, are necessarily included : while it has also become indispensable to make some inquiries respecting the nature of sensation, and of the nervous system ; though compelled, under the present moral questions, to reserve much for a distant chapter. And to this place I have also referred some metaphysical remarks, in which the last chapter is equally concerned.

My peculiar readers, entitled to the facts, as far as is necessary to the objects of this work, ought also to see the full extent of the difficulties ; that when called on to admire the power, they may know what that Power has effected. Under merely metaphysical reading, it is too easy to forget this ; as our indolence in thinking is ever ready to acquiesce in a phraseology which means nothing ; while metaphysicians have not always known

the facts, as they have often also kept out of sight what did not suit their particular views. Reversely, in possession of the facts, or with the power at least of knowing them, physiologists have written to as little purpose, or to an evil one : from want of metaphysical knowledge and habits of reasoning ; while, often, from ignorance of the tendency of their own views, or that of the reasonings which they have borrowed, they have lent themselves to the support of what they would have disclaimed, had they known its bearings ; since those have been to exclude the First Cause.

That it is hopeless at present to try to throw light on the causes of these motions, is no impediment to the object here in view, which is, to refer to the power and will of the Creator, in defect of any means of assigning intermediate causes, if such there are. But he who has read of blood stimulating the arteries, and much more of the same nature, must not fancy that he has found those ; since these are explanations which explain nothing. Under physical science, accordingly, they demand but simple contempt ; but, in the present case, they are mischievous, because their tendency, as it has sometimes been their object, is to establish a pernicious philosophy which I have often had occasion to notice. As to the following facts themselves, physiology must furnish the minute details on which I cannot here enter : and if metaphysics can explain what I have left, as I have found it, in obscurity, I recommend to the reader to seek there, the satisfaction which I do not pretend to afford ; wishing too that he may find what I have not, and understand what I have never comprehended.

If I formerly (c. 7) showed in what the complicated circle of life consisted, those actions include the invo-

luntary and minute motions in question ; comprising secretion, nutrition, absorption, and more ; while we are equally unconscious of their existence, and of the impressions which give rise to them. And at this latter subject I must commence, as the foundation of the whole inquiry ; that I may give the reader a clearer insight into the difficulties which cannot be explained without referring to a Superior power ; since, without this, it is impossible to impress the reality of that power on his mind. Thus also will he the better appreciate as they deserve, those physiological hypotheses which have tended or laboured to keep that out of sight.

Though mere anatomy cannot prove that every part of the animal body is provided with nerves, this can be inferred with as much security as a thousand other facts in science, which, equally, cannot be rendered visible and tangible. No muscle can act without nervous power, transmitted through a nerve ; and no action of circulation, or secretion, or absorption, can take place without muscular power : whence the obvious inference that there are nerves everywhere. Now, every visible nerve is connected with the brain, or other centre of nervous power, whether it supplies a voluntary or an involuntary muscle ; while if insulated by separation or tying, the consequence, in any muscle of assignable motion, is palsy ; in an organ of sense, the extinction of that sense ; and in a gland, the cessation of the power of secretion : while also, if it were as easy entirely to insulate a less significant part of the body in the same way, the event would unquestionably be the termination of its nutrition, or its death ; there being, in such a case, no other sensible consequence.

The inference is, that all power of motion, be the

nature of that whatever it may, is derived ultimately, or originally, from the brain, where at least that organ exists, as the generator and centre of this living force; whatever intermediate offices may be executed by other parts of the nervous system; as, respecting those, physiology, notwithstanding some hypotheses, is still ignorant. This conclusion may indeed appear superfluous to general readers; as even the proofs here given are familiar to every one. But those readers may not have heard of a “*vis insita*,” and of an “irritability” independent of the brain, and of “automatic motions” and “organic sensibility,” and much more of a various phraseology intended to supply the place of ideas, if not to establish a system of material machinery which was to exclude the operations of an immaterial, single, sentient principle; be its name Mind, or whatever men may choose: as it is the only portion of the human entity, respecting the eternal duration of which there can be any cause of fear.

The same organ therefore, which is the seat of mind, or soul, of consciousness, will, thought, and so forth, is also the seat of motion, and of every motion in the animal body, of whatever nature, and to whatever ends. It is, moreover, the acknowledged seat of sensation: but that it may perform the motions in question, it must also be the seat of somewhat more than is usually meant by that term. To take this question from the beginning, if the eye is irritated, tears are the consequence: a nerve has been offended; and another one is excited to exceed in a particular duty. If the sensation in this case is not felt by the brain, and the direction thence given to the lachrymal nerve, there are two seats of sensation with correspondent action: and thus there would be many

more ; as the metaphysical unity of the animal would be at an end. A sound metaphysician cannot admit of such an hypothesis ; however physiology may argue, fancying that it reasons, and deciding without perceiving what it is doing. And the conclusion is the same for every muscular action in the body, of whatever nature ; while a few of the most popular facts will be shortly noticed.

But if there are many of such impressions on nerves, which we feel, or of which we are conscious, there are many more which we can similarly prove to act on the brain, so as to excite analogous muscular motions, though we are unconscious of them, or that they are not sensations, in the usual sense of that term. There are many glands which act as the lacrymal one does, yet under some inducement, of which we know nothing, or some stimulus which we do not feel. If the instances at large are little fitted for general readers, the case of the gastric fluid is as well known as it is inoffensive ; the secretion being excited by food : while if there be some slender sensation in this case, it would be easy to quote others in which there is none whatever.

There is an impression therefore on the brain, through a nerve ; as it can be on nothing else, since that is the exclusive origin of the muscular motions which follow, although it is one of which we are unconscious. But if this should be disputed, the following familiar facts will prove, not merely that the prime mover is the organ which receives an impression, or a sensation of its own, inducing it to action, but that this transmitter of power is the mind itself ; or that the same immaterial principle which thinks, can receive impressions or sensations that we do not feel, as it also governs the invo-

luntary and unconscious actions: equally governing them without any transmitted impression, and in the very same manner, through its peculiar sensations, as mind, the seat of thought, memory, and imagination. The sight of food, in him who wants it, increases the action of the salivary glands. This, under the usual ill reasoning of physiologists, and of metaphysicians also, has been explained by the mechanical hypothesis of a communication of nerves: an expedient which the connected fact, equally familiar, renders as nugatory as it is discreditable to its inventors and abettors, be these who they may. The thought of food is as effective as the sight of it; and it is the brain therefore, as the seat of memory, or imagination, which acts on the nerves in question in this case, as it does in the others, under impressions received from without, through the intervention of nerves. If it is not so, it must then be shown that there are two immaterial powers in the body: while it would also be necessary to show, in what manner the purely thinking one should excite the other to action; and further, how the impression on the latter should excite thought in the former.

The first conclusion to which this reasoning tends, is already obvious: the further one, to which it ultimately leads, will immediately appear: but I must restate the first more fully, and separated from its evidences.

The brain, or central organ of the nervous system, is the receiver of impressions through nerves, and also the source of motion. Further, it is the seat of sensation, as that word is commonly understood, and moreover the place in which mind, exerting certain abstruse powers, resides; while all those capacities and powers belong to one immaterial principle, or a Spiritual unity, which is as-

sociated with it in some unknown manner, feeling and acting through material organs which are connected with this centre. It acts in consequence of impressions on those nerves, which we, or the consciousness, feels; but it also acts through others, which, though we can prove them to exist, we do not feel. Such impressions are therefore felt by the sentient principle; or it is capable of sensations, of which the consciousness has no knowledge, or which we do not feel. Of this we are sure, independently of the general concession that it is the sentient principle; because, in certain cases, under one impression, but in different degrees, the action is similar, and similarly follows the impression, though one of those degrees is felt by us, and the other is not. Thus also it acts in the same manner, independently of external impressions, from causes originating within itself, or belonging in some manner to its own mysterious powers; whence we are again compelled to admit, that while it is the same entity that must act in both cases, so must it previously feel foreign impressions that it may act, or even know that it is called on to act. Without knowledge, it could not do this; and that knowledge is communicated by means of sensation. And feeling without our knowledge, it also acts without our perception, not less than without our will: the case of the involuntary conspicuous motions forming the latter, as the former are those minute ones by which life is carried on.

The further simplification of this conclusion is expressed in a few words; as it is that to which the whole statement tends: while it is the great fact on which hinge all the moral conclusions respecting the power, the wisdom, and the beneficence of the Deity, not only

in this chapter, but in that future one where several questions belonging to the sensibility of animals are examined (c. 51). The mind is possessed of two modes of sensation ; the one attended by consciousness, and the other not : the latter constituting our own feelings, of whatever nature, as the former furnishes the knowledge by which it governs the body : while in that knowledge we have not been allowed to participate ; because, in the first place, we could have made no use of it, without other knowledge which we could not always possess, and other animals never ; because, in the next, we could not conveniently use it, though possessed of it : and lastly, because powers of sensation to that extent, on the consciousness of all impressions in the body, would have been highly inconvenient or injurious.

If this distinction should excite repugnance, as is the case with all new views in philosophy, especially when implying ignorance in preceding philosophers, and thus including that criticism which must be felt though it is not declared, metaphysicians should ask why it was necessary that the sentient and thinking principle should conduct itself, under all cases of bodily impression, in one, uniform manner, or why all sensation must be attended by consciousness. Under the common meaning of the term sensation, those two things are necessarily compounded : and thence probably the error ; since it is the effect of words to produce greater errors than these. It may be true, that such is the idea usually attached to the word sensation : but it is not an abuse of that word to make the present distinction, since we can apply no other to that impression on a nerve which is followed by one on the sentient principle ; demonstrated to be made, because leading

to action, and action under knowledge, or thinking, under some form. Metaphysicians at least should not mislead themselves by the sound of a word possessed of two meanings: as they must be content to use the present one, till they shall produce another. And why should the consciousness be acquainted with all the impressions on the sentient principle; or the Ego feel every thing which is felt by that? It does not feel the other mental actions which are going on in this part of our being; or it is no more conscious of the processes belonging to thought, to reasoning, memory, or imagination, which are as much actions, or conditions of mind, as sensation, than it is respecting those impressions on which the mind proceeds to act, although that Ego is insensible to them. Nay, being totally insensible to the thousand of motions in the body which are conducted by the sentient principle, and of which there are many so exceedingly conspicuous, and even violent, why must it be supposed necessarily sensible to the much slenderer movements which constitute sensation, or conscious of all that is felt by the sentient principle? It is further notorious, that consciousness and sensation can be separated, under certain circumstances, even in those cases where they so usually accompany each other that the vulgar idea of their community is apparently justified. This is the history of somnambulism: an impression is made; and the mind, feeling it, acts on that as it would have done in the ordinary cases; though there is no more consciousness of the impression than of the action. And though this illustration may be evaded by words, or by saying that there is defect of memory only, and not of consciousness, it is of little moment, since it is not essential to the present view. But it is an obvious

metaphysical question, to ask what consciousness is, and why it should necessarily be attached to all sensation on the part of the sentient principle? It would be difficult for metaphysics to answer this question, when they have not succeeded in defining its nature, or the mode of mind to which it belongs. But if it is connected with that mode, or proceeding, of mind, which is termed reflection, then is it especially easy to see, how consciousness can be separated from sensation, since it is not metaphysically necessary that the mind should reflect on an impression received; above all, if the laws for its conduct are, that it *must* perform the actions consequent on those, which are necessary to life; in which case it ought not to reflect: while seeing, in everything, that the maintenance of life was the prime object of the Creator, we can the more easily admit of this compulsory action without reflection, and thus, consequently, of sensation without consciousness.

If I have not here space to extend these metaphysical reasonings, as I have not room to write a book on every subject treated in this work, a few facts belonging to the nervous system, especially as those relate to the final causes of these appointments, may render them more acceptable, in proving their utility, or necessity, under that wisdom by which we profit, while we either do not study to discover it, or will not acknowledge it when the results are obvious to us. And it is the argument from final causes which I have so often used. The appointment was indispensable to the wants of the animal, or to the purposes of the Deity in creating it; and therefore it must have been made, and does exist; else would He have been unwise, or inefficient: which cannot be.

Certain senses have been provided for the purpose of communication with the external world ; while, on those five leading subjects, this was indispensable to the animal, or rather was a part of the total design. And to the nerves of those senses it has been commanded to convey to the mind, impressions attended by consciousness, because that was the ultimate purpose here in view. As far as we can see, it was an arbitrary law, for use, or for a final cause : we are too ignorant of mind, to say that this was a necessary part of its constitution : yet it has been tacitly assumed to be such, when we suppose that all sensation by the sentient principle must be attended by consciousness. And, reversely, if such sensation, without consciousness, can be proved equally necessary, we ought to believe in its existence, on the same grounds ; as we possess no knowledge of the constitution of mind to induce us to say, confidently, that it cannot exist. Sensation, in the common meaning of that term, was necessary to the animal, as an incitement to its needful motions, under various purposes : as it is a law of the nervous power that it shall act, in return for being acted on, in some mode or other ; and not otherwise. But it was not necessary that the animal should perceive, or be conscious of all those impressions which incite to every motion in the body, as needful to its welfare as the former : on the contrary, it has already been shown, as it will further be confirmed immediately, that such feelings would not merely have been useless, since the conscious being could not have acted upon them so as to have executed the necessary duties, but so injurious as to have defeated the very objects of the design. And therefore the consciousness has been separated from one class of sensations, as it has been given to the

other ; this latter constituting the several senses. And the singularly definite nature of those, with the peculiar provisions made for them, in nerves which perceive only one species of impression and not another, as is the case in comparing any two, seems to prove, that there has been some especial contrivance exerted in this case, or that some means, which we may hereafter ascertain, have been adopted, even in the mechanical structure of the animal, for associating consciousness with one impression, and separating it from another. If physiologists have produced some hypotheses tending to the same conclusion, though under vague notions of the subject and a lamentable deficiency of metaphysical knowledge, in assigning to the ganglia the power of cutting off consciousness, it is that hypothesis, already noticed, though they have not seen the consequences ; which would give to these an independent power of action, as of sensation, and thus establish a plurality of sentient and directing principles. In the meantime, if nothing that we yet know can elucidate the mode in which this remarkable distinction is made, we can always rest in the conclusion that it is an appointment of the Creator for useful purposes, or an arbitrary law for an end : using the term arbitrary, only as excluding intermediate causes, since, under a moral view, every appointment on His part is equally arbitrary.

If there are certain facts and analogies belonging to the nervous system, which would seem to prove, as I just said, that the contrivance should be sought there, it is one of those common cases, where the superficial aspect of a subject deceives us into the belief that we have effected a discovery ; as it is thus the frequent source of hypotheses which a little more accuracy of reasoning would have suppressed. Yet as the facts are interesting

under this brief and partial sketch of the nature of the nervous system, I may note them; especially because they also bear on the question of sensibility, discussed in a future chapter.

It is proved by anatomy, that the nerves which convey the power of motion, and those which convey common sensation, are distinct; and there are inferred therefore, two species or structures of nerves, the sentient and the motory. Yet this, whatever may be its value, is but vague; while the vagueness consists in the general term sentient. Nor was it ever imagined that the optic nerve could be a nerve of motion; so that all which follows from this vaunted discovery, is, that the same is true of the nerves of touch; as it is of every other sense, or of every nerve of sensation. But this can be but a small part of the whole distinction. The nerve of one sense will not convey the impressions which are carried by that of another: and the nerves of the several vital organs differ in such a manner, that the same substance which is strongly felt by one, as it excites to corresponding action in the sensorium, makes no impression on another; while some of those otherwise insensible nerves are so delicate, that, as in the heart, they can feel the difference between venous and arterial blood. And thus it might equally be argued, that if the nerves of unconscious sensation cannot be stimulated so as to make the animal feel, so they must differ in nature or structure from those under which it does feel. But true as this may all be, it leaves the difficulty just where it stood before. Impressions of sensation are conveyed to the sentient unity, and why, therefore, if the consciousness knows of some, why does it not know of all? Reserving the selected cases of unconscious impressions and actions, as the examples

and proofs of the Divine wisdom under these mysteries, I must now briefly note some of the hypotheses on this subject; not for any purpose of scientific criticism however, but on account of that pernicious moral tendency to which I have alluded. And, under the present object, that is indispensable; since phraseologies of usage and habit are always influential, till their want of meaning is shown.

The term irritability constitutes the briefest hypothesis which has been offered in explanation of the chief difficulty on the existence of unfelt impressions on nerves: sensation without consciousness. And while, perhaps from its very brevity, it has had most success with those who will not think, or cannot, so has it best escaped criticism. But it is a mere word, explaining nothing. The membrane of the nose is irritated; and a hundred muscles are put into violent action. And thus, without end. There is no independent power of sensation, determination, and action, in those several parts: it is the answer given before. There is a feeling and an acting centre, which connects the sensation and the effort; the injury with its remedy. And this is further proved by the facility with which we trace a sensation of consciousness, through a diminishing gradation, to one where nothing is felt. Under this hypothesis, the imaginary irritability should be the case of action in the one case, and the sentient mind in the other.

I need not inquire of this hypothesis, in the case of actions from impressions divested of consciousness; as I cannot pretend to answer it, here, under the same extent which it has occupied. The general answer applies to all. And the term *Vis insita*, of Haller, can scarcely be distinguished as a separate hypothesis;

while the tendency of both is the same: being that which would establish a system of material machinery, independent of a vital and thinking and governing principle, Mind. If it is painful to see a philosopher of his known piety misled by want of reflection or the love of hypothesis, so are the most common physiological considerations sufficient to set aside this *Vis insita*. The motory nerves retain, for a time, a portion of that power which they derive from the brain, though separated from it; as there are also animals, under many degrees in descent from the higher kinds, where that power is not so definitely centred as it is in those. The application of a stimulus to those nerves, puts this power into motion, in the separated part, as it would have done in the entire or living animal; this is the supposed *Vis insita*, or the imagined irritability.

If terms pass for theories in this species of philosophy, so does an old hypothesis pass for a new one, by the invention of a new term. "Automatic motion," and "organic sensibility:" these are now the phrases. Yet they are but the correllatives of each other: while one explains the one-half of the subject, just as the other elucidates its own share. If an organ can feel, I have but to repeat the metaphysical remark respecting the unity of the mind; as it equally applies to the phrase, automatic motion. But there is a peculiar ignorance, in the very terms, as thus applied. If it is meant to say that the will moves some muscles, but that others move themselves, it is not true: since the will moves no muscles. The one set are as automatic as the others: and end is desired; that is all: and in each case alike, there is a ruling power that moves them, but under different inducements; of some of which, we have no consciousness.

If the examination of this set of hypotheses might fill a book, under the usual manner of dealing with those subjects, I have said quite enough respecting such philosophy as this. It may amuse or interest the reader to notice some that belong to a very different philosophy and age : as this also will not be useless under the present object, since it will show how little real variety there is, with equal feebleness, in all these attempts to establish modes, if not systems of a materialist philosophy. Yet the imaginative, or poetical, character of some of those, renders it probable that they were never seriously believed ; being merely the occupation of minds unacquainted with the paths of a rational philosophy, and apparently as insensible of its value as its nature.

The “*spiritus qui intus alit artus, et toto se corpore miscet,*” will remind the preceding theorists of what they had forgotten, or inform them of what they did not know. Whether they have merely coincided, or borrowed, yet from philosophers much more modern than Virgil, they can now perceive that they have been supporting Epicurean doctrines : though I know not that I should thus explain, and thence censure, a passage which may only refer to that Platonic theory which he who has had the reputation of it borrowed from the Hindoo philosophy ; censurable nevertheless as it is, on other grounds, and in the words of Cicero. “*Quomodo porro Deus iste, si nihil esset nisi animus, aut infixus aut infusus esset in mundo ?*” Is this not, or rather has it not often been, little other than a better sort of materialism, into which Thomson, Pope, and more might be accused of having unwarily fallen, had they been writing as metaphysicians instead of speaking as poets ? The doctrines of Spinoza are not very different.

It was another hypothesis of the same age, which considered man as consisting of a body, a soul, and a spirit; thus separating the power which animated the body, from the thinking principle. It would be more amusing than fitted for this place, to point out some of the consequences deduced from this doctrine, and I must therefore content myself with referring to Lucian, at least. But, borrowed in far later days, and extending even to our own, thus do we find the astral spirits of a mystical philosophy; becoming, among much more, the basis of a well-known species of imposture and vaticination, the so-called Second-sight. Thus also on the subject now in question, did the astral spirit become the Archæus of Van Helmont: so little of invention is there, even when the imaginations of men renounce all restraint.

As a pure hypothesis however, explanatory of that mystery under which the body is governed without the knowledge of the consciousness, that of Van Helmont is perfect: a merit which we cannot concede to those of the physiologists; since they are equally clumsy and inefficient. To those persons who believe this theory true, because they think it proved by Scripture, it would be purposeless to say, that the apostle is but using a common salutation belonging to the Greek philosophy of his age; and that the message respecting his cloak might, with as much justice, be deemed the result of inspiration.

I have yet to notice that hypothesis of modern metaphysicians, which has adopted the term "association" as its basis; though effecting little, when it leaves most of the essential difficulties unexplained. That Hartley, a physician, should not have seen this, is surprising: as it also is that

Locke, similarly informed, should have adopted what he has, respecting the nervous system. But physic was then under the trammels of the mechanical philosophy : and this must be the excuse for men of such powers of thought : as the pursuit of an hypothesis will also blind the strongest judgments. It is easy to see that association is but one of those terms, like irritability, which govern men, because they are not examined, and not analyzed in their applications : while it is also nothing more than the sympathy of the physiologists, and equally a progeny of the mechanical philosophy. The term is indeed more vague ; and therefore the better admits of that interminable discussion which it has experienced ; as it has also attained more success, if recently under a new word which I will not quote, for the plain reason that it is most difficult to controvert what is least intelligible : as thus it is that metaphysical writing becomes interminable as it is obscure, and thence the never-failing source of new controversies. It is not within my province or limits to discuss this question with metaphysicians in their endless language ; as all who take any interest in it know where to seek. For my purpose, it is sufficient that the objections already made to the other hypotheses apply equally to this one, and will be found in the preceding parts of this chapter.

In concluding this very brief, but sufficient, sketch of hypotheses, I need only add, that if they are all to be rejected, and if we will not believe in the separation of consciousness from sensation, in the same spiritual entity, we have then no resource but to suppose that a superior being is ever resident in the animal body, performing what the consciousness knows not, and the will does not execute. This would indeed be a species of

Archæus ; but it would be God himself, under the views at least of the Hindoo, or Platonic system : a solution, I presume, the least acceptable that could be offered to many of those who have laboured to explain the facts on other views of their own.

Referring also now to the last chapter, I may proceed to the further cases of involuntary motions which I have selected, partly as examples under these facts relating to the nervous system, but principally as examples of the wisdom and goodness, not less than the power, evinced in its construction and regulation.

The Heart claims the first place, from its connexion with the subject at which the former chapter stopped. This singular, as important organ, must possess an appointment of alternate action, independently of the alternating stimulus of the arterial blood : not because it continues to act thus, when separated from the body, in the cold-blooded reptiles, since this might be considered the effect of habit, but because it does the same in the chicken, before any blood has been circulated, or visibly produced. But that it acts also through the stimulus of arterial blood, is certain ; because it ceases to act under blood which has not undergone the necessary change in the lungs. I must also point out that singular provision through which it is appointed that it shall not tire. We are less struck with this in the sphincter muscles, because a perpetual state of contraction seems the natural condition : but knowing that there is a moment of rest in the heart, we can imagine that it might refuse to recommence, as the mere thought is alarming to persons of intense imaginations. That, even disorders its functions : proving that even over this involuntary muscle the consciousness can exert power, as even the

will is known to do, in certain disordered states in the nervous system. It is one of the cases already alluded to, to prove that the separation of the voluntary and the unknown power is not always perfect, even as to one organ and action, and that both therefore belong to the same entity. It is also an instance to prove, that while there may be extreme nicety of sensation in nerves respecting which the consciousness is ignorant, feeling no sensation, so are there nerves of specific feelings, even in this class ; since even the tongue cannot distinguish between venous and arterial blood, as the ventricles do.

If I need not pursue this inquiry to the larger arteries, where the facts are similar, I must notice what occurs in the ultimate branches, as the organs of secretion and nutrition : the latter of which cases offers a peculiar difficulty, as will shortly be seen, since it seems to demand the presence of a power higher than that of the sentient principle, even under the view here given of its singular nature. But I must commence with the process of secretion, as being the least difficult of the two.

In the case of the lacrymal gland, where there is a secretion in excess, we know that sensation is the cause when the eye is irritated ; as this is also an example of remedial action through the intelligence of the sentient principle, since the train is circuitous. In every other instance of the increased secretion of a gland, although no sensation should be felt, we must draw the same conclusion : and still more must we believe the Mind to be the mover in the first case, when tears are the consequence of grief, since there can be no corporeal impression, of any nature : while, of this singular consequence, we can conjecture no purpose, since it is not remedial.

And were there not a central discerning principle, which we must believe to be an intelligent one under some form, it could not vary its action so as to meet the variable wants of the body, as it does, in this case and others, under sensations received, and we may almost suppose, reasoned on. It would be easy to cite many illustrations under ordinary secretion : but the case of separation, immediately to be noticed, will serve as a sufficient example.

This case of secretion serves also as the further proof of a fact already stated : the specific sensations of certain nerves. If it be considered a mere act of separation, according to the old mechanical hypothesis, one vessel must possess a choice for a certain portion of the blood, and another for some other one : while, though chemical, as we are now sure that it is, there must still be specific sensation, or there could not be specific action. The old mechanical hypothesis has indeed been lately revived, under a far more barbarous and ignorant form, by the new system of pores, organic and inorganic : as it has been received, because it is the latest novelty. It would be trifling with a reader to answer it, after what has preceded : as to answer it now, himself, will be to form a clearer conception of a subject which cannot but be still somewhat too abstruse for him who has not been practised in such inquiries.

The process of absorption offers another example of those involuntary and unknown muscular motions. Taking the lacteal as the fittest for this purpose, its orifice must be a sentient, as well as an active muscular mouth ; since it chooses and rejects. Though it must not, however, be supposed capable of knowledge respecting the body at large, it must also be guided by a

knowing principle ; which, feeling through it, acts also through it, aware of what is required elsewhere ; since the little instrument is voracious in proportion as the body at large is in want, or the stomach hungry. Yet itself has also a chemical choice, like the secretory vessel ; since it chooses what is good, and rejects what is pernicious and useless, even out of a mixed fluid. And of all this, sensation and motion equally, we neither know nor feel anything.

The last of the involuntary muscular motions are those concerned in the operations of nutrition ; or the increase of the infant structure, in the first place, and the reparation of waste afterwards : while they are intimately connected with the process of secretion : the former being but the secretion of a solid, speaking chemically, as the latter is that of a fluid : though the greater distinction consists in the variety and the minuteness of the applications.

Whatever may be the fact in the former case, in the latter there must be some sensation transmitted to the sentient principle. It is not the consistent procedure of a pre-established system of operations, as the original growth of the body may be supposed ; since the separation is contingent, and also unequal, and depending on the exigencies. The sentient principle knows, not merely of a general want, but that there is an unusual one also, and further that there is a specific, or a local one : as it could not know this, but through a sensation transmitted by the parts, though, as in other cases, it is one, of which we have no knowledge. The illustrations are familiar : since this is what must occur after extenuating diseases, or under hard labour or certain excessive secretions, in the first case ; as the instance of a black-

smith's arm and the legs of a dancer, are even more familiar examples of the other. Thus is even the strength of the bones of the legs in horses increased by exercise.

But this case of local reparation is so remarkable as to call for a distinct attention. There is a demand for unusual nutrition by those parts, or for more than is required by the average wear of the body, or by the other portions of the machine. And that unusual call is complied with. But even more is granted: for the supply exceeds the demand. The parts are not merely restored more quickly, and in equal quantity, but there is an anticipatory provision. It is known to the ruling principle, in some manner, that the same supply would not suffice for the unusual demands on exertion; and therefore the parts are enlarged, or strengthened, that they may be enabled to execute the extraordinary duties imposed on them. If the sentient principle, presumed to be a separate one, is not also intelligent, or if there is not an Archæus, then must the intelligent and reasoning mind which we feel and acknowledge, understand and reason, without any more consciousness, on our parts, of its knowledge and its reasonings, than we have of its sensations. And this again confirms the former views of the nature of the mind, yet more amply: since it shows that even its higher powers may be exerted without our consciousness, as its power of sensation is: while if this explanation were doubted under the present case, it is confirmed by the analogous, if less remarkable facts, where trains of reasoning are carried on under dreaming or somnambulism, or under what is termed absence of mind during wakefulness. If this solution is not the true one, we have no resource but in

that supposition respecting the Deity, which I need not repeat: since, utterly weary of the “stimulus” of physiologists, I will not again dwell on the especially egregious ignorance of its application, under the present, and, far more, under the following general fact, the reparation of injuries; since stimulus implies sensation, while, the action implying intelligence, there must then be a special intelligence everywhere.

The system of reparation under injury, to which I have thus alluded, being also a mode of nutrition, is even a greater difficulty; if it is not sufficient to form a difficulty, that it is an inexplicable thing; since it implies more knowledge, as it demands more exertion, and with new actions, or contrivances, of which there is no example or precedent, in the usual condition and proceedings of the Machine. The facts are familiar, while the mystery is neither considered nor valued. A wound heals, or a broken bone is reunited, or a new nail grows to replace an old one: as, far more, of a reparatory, or a preservative, or a compensatory nature, occurs: all calculated to place the structure in a position as useful as it was before; within certain limits of injury on the one side, and of expedient on the other. If many of those facts are but little known beyond the bounds of surgery, all have heard of a new, supplementary, joint, formed by the ligaments and muscles, in cases of dislocation; of bullets buried with impunity, through a formation of new parts; and even perhaps, of the substitution of a new bone for one that has perished, and of the enlargement of lateral arteries to compensate the obstruction of a principal one: as there is far more which physic knows, and which I need not name.

But to render sensible the differences, between the

conduct of the ruling principle in these cases and those of ordinary nutrition, and also in those where a special supply is furnished for peculiar excesses, I will select the simplest example among the preceding; since, while it will suffice for my purpose, the facts are known to every one. When an atom of skin, unknown to us, is rendered inefficient, under the usual wear of the body, the sensation of a want is felt, and it is supplied, under an arrangement, of which, we have neither perception nor demonstration. If however ten thousand atoms are suddenly rendered inefficient, or removed, the sensations become proportioned; and attempts are made to replace the parts, or repair the evil. But as the ordinary process is insufficient, there is produced, if not a new set of secreting or nutrient arteries, that which is equivalent, a new modification of the existing ones, and a new gland, if I may use such a term, producing a fluid secretion unknown in the original structure, together with a new organic solid, through which the desired end is effected. To things so familiar, I need not here apply the usual disgusting terms; as even their vulgar familiarity tends to divert the ideas from the important philosophical views which are here so necessary.

I need not extend these cases, of accident or injury, since the reasoning is the same; and still less need I inquire of the reparations provided for the multiplied cases of internal disease, since that would far exceed my bounds; while the general conclusions must ever be the same, however the circumstances or the modes of reparation may vary. If certain modes of injury were foreseen, so, doubtless, were certain diseases; while, if everything is not reparable, as, unquestionably, it was

as little intended that everything should be repaired, as that the body should not die, still, under every apparent variety, the modes of reparation are referable to a few simple principles, though, even then, neither are the difficulties removed, nor the wisdom and beauty of the provisions less admirable.

But although that which the hypotheses of physiology have not yet explained, and which I assuredly cannot, should for ever remain inexplicable, this at least may be inferred, as it is the inference which imports us here. In the first case, the Creator of the animal body knew that it would be sometimes called on for excess of action, as He also knew that there would be no bounds to those attempts, under the freewill of the animal, but want of power. Within those limits which pervade creation, in everything, as some limit must have been appointed, He has granted excess of power, to meet certain necessities, or excesses of will: and for this end also He has commanded, that the sentient principle having the charge of nutrition, should, on the demand, through sensation, and unconsciously to us, not merely supply the want, but do more; that the possibility and the power might be given, as far as the limits which He had appointed for such exceedings. And in the second case, we must equally conclude, that the provisions for the repair of the body, under whatever species of injury, have been committed to the same power, and in a similar manner; through sensations, with consequent actions; yet, as before, within certain appointed bounds. Both of these are modes of nutrition, as they are the work of the same power which similarly produced the full-grown body from the germ: but the last case differs materially from the first, be-

cause it implies a process of an occasional nature, not belonging to the current actions. Yet there has been some original appointment for this purpose also: as will more plainly appear in considering the cases of reproduction in the inferior animals, where there are partial as well as general ones, as in that of the legs of crabs: though no more indications of this are found in the sound body, than there are of the process for healing wounds; as these provisions also may never be called into action.

Under the different views of the animal structure which have been given in this work, I have occasionally drawn some conclusions which follow even more strikingly from these last statements. In providing for the permanence and efficacy of the animal structures, under appointments so difficult to understand, we see foresight, a knowledge of all that would or might happen, with a resolution not to be defeated in the intentions for which these were arranged. This is not the work of an Artist who took no care for the future: since there is provision for the future and the possible.

If, in the last chapter, I pointed out the wisdom which had taken the power over the muscles there examined, out of the hands of the conscious being, the present one demands some further remarks of the same nature. Had every feeling of the sentient centre, necessary for conducting the machine, been a sensation to the conscious animal, we cannot conceive a power of discernment left for aught else, as it would be difficult also to imagine an exemption from extensive suffering. Had there been a consciousness of all the subsequent minute muscular actions, it is but to suppose a vast increase of the evil stated in the preceding chapter. But

had it been further necessary, that these should have been governed by the will, though it were no otherwise than as the voluntary muscles are, it is to complicate the inconveniences in a manner that I need not dwell on: as it would especially be to make calls on the attention and time of the animal, which could not have been complied with.

But did we even imagine the intelligent animal so constructed as to endure and execute all this, it would be impracticable to the unborn one, at least, if not to the infant also: as the case of the inferior animals is even more striking. In some of those at least, there is not a trace, nor scarcely a suspicion of an intelligent mind; yet all these things are executed in them, in the same manner. But the mystery is hopeless: and it is as fruitless as it would be easy, to accumulate words on it. Is there a spiritual entity in even the lowest animals, which knows what is wanted, and executes what is to be done; working with knowledge also, since nothing but knowledge can work under contingencies? Is there an Archæus here? Then must there be one also in plants; for the essential portions of the preceding reasonings apply equally to them. They receive impressions, and they act in consequence: they receive impressions in one part, or they act with another: and they also vary their conduct under contingencies. In what or whom does this perception lie, and whose conduct and action is this: and who also is there that will undertake to separate the plant from the animal, under this case? It is God, still: but His mystery He has not allowed us to penetrate.

To end. The structure of the animal body is one of surpassing ingenuity and complexity; but even that is

almost forgotten in reflecting on the extraordinary appointments by which it is put into action : and if I have dwelt on those at some length, it is because they are scarcely imagined by those who have a sufficient general notion of the structure and functions of animals, and because the labours of too many physiologists and metaphysicians, if the term labour can indeed be applied to their hypotheses and their phraseologies, have, in elucidating nothing, either neglected the incomprehensible Artist by whom all this has been ordained and effected, or in the vanity, or worse, of their wretched reasonings on deficient observations, forgotten or doubted their God.

CHAPTER XXXII.

ON WATER.

THE philosophy which considered water and air as simple bodies, and termed them elements, has long been antiquated, on these and other points, by a science then unknown. Chemistry has proved that they are compounds, and is desirous to think that it has assigned their composition. With respect to the atmosphere, it is assuredly not yet fully informed: and, that it truly understands the chemical nature of water, is much more than doubtful: as might here be easily shown. Yet it has done much as to both these great bodies; of exceeding value under the present views, while of great moment in mere science. Thus can natural theology now contemplate them in a far other manner than it once did; as they can be shown to operate the most splendid and beneficial effects in nature. They were indeed great contrivances in the eyes of this science, when only their mechanical properties were known, and when even their chemical actions were believed to be mechanical ones. They are far greater to us who know the value and the immensity of their agencies under the great power of chemistry: and the more striking, when we find that such numerous uses, under both chemistry and mechanics, are attained through inventions of perhaps as great a simplicity as creation affords.

I shall not here speculate on the mode in which the Creator formed, or might have formed, these two great bodies : it may be conceived, generally, under chemical laws, but not in its details : and I have noticed this matter elsewhere. It is more interesting for my purpose to show that they were created for the sake of animal and vegetable life, and to point out the most striking of their properties and uses. If I have placed them under the attribute of Power, this seems the place especially claimed by all the great bodies and agencies of Creation : yet it will be seen that they evince the most admirable contrivance, or design ; that they prove the Wisdom which attains great ends in a simple manner, and many ends through limited agencies ; while they also offer evidences of Goodness in their uses to animals.

Is there any one who can elevate his mind above that indolence of observation and dulness of feeling which result from the daily impressions of familiar objects ? There are such ; for of them is he to whom nature has granted the power of seeing her as she deserves to be seen, and of teaching others how she ought to be contemplated. It is the poet of nature who should write the history of water. Familiar, even to neglect, this is a wonderful substance, and we forget to admire ; beautiful, and we do not note its beauty. Transparent, and colourless, it is the emblem of purity : in its mobility it is imbued with the spirit of life : a self-acting agent, a very will, in the unceasing river, the dancing brook, the furious torrent, and the restless ocean : speaking with its own voice, in the tinkling of the dropping cavern, the murmuring of the rill, the rush of the cascade, and the roar of the sea wave ; and, even in the placid lake, throwing its own spirit of vitality over the immoveable objects

around. And if its motion is the life of the landscape, it is, at rest, the point of contrast and repose for the turbulent multiplicity of the surrounding objects: a tempering shadow in reflecting the bright picture, and, as the mirror of the sky, a light amid darkness; while it is the colour to enhance what it contrasts, whether in its splendour or its shade.

Its singular oppositions of character are not less striking. Yielding to every impulse, unresisting, even to light, it becomes the irresistible force before which the ocean promontory crumbles to dust, and the rocky mountain is levelled with the plain below; a mechanical power whose energy is without bounds. Of an apparently absolute neutrality, without taste, without smell, a powerless nothingness, that deceptive innocence is the solvent of every thing, reducing the thousand solids of the earth to its own form. Again, existing at one instant, in the next it is gone, as if it were annihilated: to him who knows not its nature, it has ceased to be. It is a lake, and in a short time it is nothing: again it is that lake, and it is a solid rock. It is rock crystal at one instant, and in the next it is invisible; while the agent of its invisibility transports it beyond the earth: that rock is air. Thus sailing the heavens, it descends again, unchanged, again to renew the same ceaseless round: for ever roaming between the earth and the vacant regions of space; wandering about the earth below, in the performance of its endless duties, and though appearing at rest, resting nowhere. This, and more, is Water: powerful in its weakness, and powerful in its strength: an union of feebleness and force, of incessant activity and apparent tranquillity, of nullity and ubiquity, of insignificance and power, a miracle of creation.

I must commence by examining this substance under its chemical relations : for in these lies that great source of its wide utility, of which the philosophy of former days saw nothing. Had it been the simple substance which it was once thought, all its mechanical uses would still have remained, but the living world would not have existed to profit by them : so eternally true is it, that the more we study the works of the Creator the more we learn to know Him. The highway of navigation, the atmosphere of fishes, a moving force for the uses of man, the distributor of soil and the agent in creating new lands, it might also have been the source of the clouds and the rains, the universal purifier, and much more, under those properties which it was once thought alone to possess. But it would not have been the food of plants, and thus, of animals also ; it would not have been the great provision for renovating the atmosphere ; and it would not have formed that soil which its mechanical force distributes : as, without the properties which give it those powers and far more, chemistry, under a thousand modes, would have been without its right hand. All these ends, and more, did the Creator of water intend to derive from it ; and He has created it accordingly, a compound and a decomposable substance. And, be its composition truly known or not, be oxygen and hydrogen simple elements or otherwise, it is indifferent for the present purposes. Though our philosophy should be imperfect, the conclusions of natural theology will remain true : thus independent are efficient and final causes.

Though water is, remotely, the source of the feeding of animals, it is not directly their food, as far as is yet known : while I have noticed this difficult question elsewhere. But it is indispensable to their nutrition ; as

it is to the very existence of their mechanisms, independently of all addition of new matter. Chemistry can now inform the mechanical philosophy, that its solvent power is the result of chemical energy: nor will it longer allow that philosophy to say that the needful fluidity and flexibility of the animal machinery is effected by the mechanical power of water. Thus also is it that body, or contrivance, without which the animal mechanism could not have been formed from the germ by the vital ruler of chemistry, and could not have been repaired under waste.

But it is, far more essentially and intimately, the source of nutrition to vegetables; as it is decomposed by them: one of its presumed elements, hydrogen, being a part of their food, and constituting a large portion of their structures and productions, as does the other, if in a far less degree. This indeed is the greatest of the chemical offices performed by water; while nearly all else is subsidiary or accessory to this great and splendid purpose, equally, if more remotely involving the nutrition of animals. The foundation is simple as it is beautiful: it is one of the cases in which, as in gravitation, we really trace the simplicity of the Creator's contrivances. But there is more than one kind of beauty here involved: and I must not pass over, at least the chief displays of this.

Every organized structure can exist but through the supply of fresh materials, or of food. With few exceptions, animals have been empowered and compelled to seek it: but the very nature and necessities of the vegetable forms prevented this. Their food is therefore brought to them: it surrounds them on all sides: the Creator feeds them with His own hands, through His

great agent, chemistry ; if aiding it by the mechanical powers which He has also commanded. An essential part of that food is in solution, and the ocean is its great storehouse. It is taught to ascend into the atmosphere, to pervade the circumambient sphere of the firmament, to return that it may visit every vegetable existence, to surround them in the air, to be present with them in the earth, to be ever near them and about them. It is brought to their mouths at every instant, and nothing is required of them but to feed and to enjoy. Thus has their great Parent amply compensated them for that of which He was compelled to deprive them, in conformity to the wisdom of His general plan. We know not which most to admire : the magnitude of the problem, or the beauty, the perfection, and the facility of the solution. But, that we may admire, let us suppose that it was to be solved, that the feeding of such a mass of living and craving, and yet immoveable beings was to be effected. Yet because it is effected, we forget that there was a time when it was to be done : because it is effected in silence, with regularity, and with certainty, we forget to note it : and because of the perfection of the solution, even philosophy has forgotten to admire.

The Creator formed a class of living beings. They were to crowd the earth, yet not permitted to quit the narrow point to which they were chained down. They were to commence in an atom, to attain a large bulk, to perish, and to be renewed. He appointed chemistry for these purposes, and He commanded life, to rule it. This demanded materials ; and these were to be placed within reach of the instruments that were to use them. Those materials were spread far and wide : while the myriads of beings were incapable of seeking what was

essential to their existence. The plant was fixed to the dry and burning sands of Africa, and its food was many thousand miles away, wasted and useless in the wide ocean. But for His wisdom and power, every plant of the earth would have been but as a grain of wheat on the naked rock : created but to perish at the moment of its birth, to die of hunger. All must have perished, but for Him who has solved this great and difficult problem. Can man contemplate such a creation, unprovided for, and then say that he could have devised the means of feeding it? He will not say this, if his philosophy is of that true kind which acknowledges that it knows nothing but what God has taught.

Though reserving to the next chapter the nature and utility of the atmosphere, I may here point out the beauty of the contrivance through which the same operation supplies the food of the vegetable tribes and the respiration of the animal ones. It is an example of that simplicity which it is delightful to trace where it is really visible, but which there is no advantage in assuming where it cannot be found.

It is through the decomposition of water that it becomes the food of plants ; and the chemistry which effects this has been placed in their own power. They devour, they appropriate, and they reject. They might have appropriated the whole : but thus would not this beautiful contrivance have existed, and the animal races must have been supplied, in some other manner, with what was as indispensable as their food. The same chemical action fulfils both ends : the oxygen which the plant does not require is discharged, an air, into the free atmosphere, and becomes the supply for the other half of the living creation.

This is the solution, simple, and at the same time effectual, of another magnificent problem. We do not indeed know that this is the only manner in which the oxygen of the atmosphere is renewed: yet thus, partly at least, is this incessant supply for an incessant consumption provided. And thus are there two circles of nutrition between plants and animals, in each of which the plant is the initiative agent and power. The animal could not have extracted from water, either food or the material of respiration; as necessary as food. The other furnishes it with both, through the same vital chemistry by which it maintains its own life: and the material whence it draws and distributes these resources of the whole living world, is the element Water: that apparently simple, insignificant, substance, of which the ignorant and the thoughtless see little but that it falls in the rain, circulates in the rivers, and fills the ocean.

If water is the residence of the multitudinous creation of fishes, it is rather their atmosphere than their abode: to them, it is what the air is to the birds. Yet it is superior in adaptation and convenience: for its inhabitants can rest in it, without labour: the whole arrangement indeed presenting one of those beautiful adaptations to which I have given a brief chapter, and much more worthy of attention than those scarcely avoidable ones on which it is the custom of slender writers to dwell. Nor must the effect in question be called a necessary result of the superior gravity of water: since the weight of these animals is not only nicely suited to this, but there is united to the whole a system of subadaptation to meet variations and exigencies, by the beautiful contrivance of the air-bladder. The mus-

cular power of fishes is restrained, in point of endurance at least, in consequence, apparently, of their confined respiration, though an anatomist of note has made this rule too exclusive; and thus water, as the medium of flying, which swimming may for this purpose be termed, relieves, by its weight, the muscular efforts of the animal. The bird is called on for a double exertion: the fish for only one.

But the water is also the chemical atmosphere of fishes; and thus does a distinct contrivance become necessary. Under analogy to air, their gills should indeed have decomposed it, and thus have effected the needful purposes. This however is not the process adopted; for whatever reasons. The water is ordained to combine with air, and thus to furnish what is required: while the consumption is for ever replaced, probably by the agitations of the former in contact with the atmosphere. It is a distinct chemical property, and, but for experience, would not have been supposed. Like all else that was needed, it has been commanded, and it is done.

If water is a mechanical atmosphere for fishes, so is it, in a certain sense, for the uses of man. It is the highway for his ships; and they fly along its surface, supported like the former, and winged like the birds of the air. Was this intended or incidental? Is there anything of all that was foreseen by the Creator, (and what is there that was not) which was not also intended? and is it any proof that this, or aught else of apparent contingency was not, that we find many purposes effected by one contrivance? The opposite conclusion would come with an ill grace from those at least who argue for simplicity of design in the works of the Deity:

yet it is by these very persons that the doctrine of contingencies, the absence of intentions, has been maintained. His foreknowledge and His will are one, inasmuch as they are Himself: that will, He has carried into execution through means: and if the means are not always peculiar and exclusive, it is still of His will that the effects are produced.

Of whatever importance may be that chemical power in water through which it can dissolve air and hold it in solution, far more extensive and splendid results follow from this combination when the proportions are reversed, so that water is dissolved in air and becomes a constituent of the atmosphere. This forms the basis of clouds and rain. The philosophy of this subject is indeed still obscure, and, perhaps, mainly from our ignorance of the actions of electricity; so that I must content myself with the facts, while, in pursuing them, it becomes impossible to separate the chemical from the mechanical considerations which belong to this subject, as, fortunately, under the present purpose, is not needful.

I already alluded to the disappearance of water and its conversion into air. In the common operation of boiling, the water itself becomes an air, but it requires a high temperature to preserve it in this condition. The ordinary evaporation of this substance requires however but little heat; for even ice evaporates: and, be the exact process what it may, the water is united to the air, or they form a chemical compound possessing the mechanical properties of the pure atmosphere. It has disappeared; and in as far as it was fluid water, has become idle, inactive, useless: but it has been placed in a new position, where it is still ready for its ordinary uses, and also ready to be transported wherever it is wanted.

It is then transported ; it returns to the earth, unchanged ; to where it was deficient, from the place where it was superfluous : and thus does it reach even that mountain summit which it could have attained in no other manner, to descend again, and renew the same indispensable round. It was a great problem to render a substance lighter than that which was a thousand times lighter than itself, yet without affecting any of its appointed properties. Who is there, knowing the power of gravity, and not knowing this fact, that would have believed it possible ? As an abstract statement it would be denied : yet the same Hand which ordained gravity, has found no difficulty in counteracting it whenever that was needed, and no difficulty in dissolving cohesion when that would have been an obstacle to His views.

But this is not all the mystery : far from it. Chemistry is indeed desirous to think that it can explain the process, when it speaks of the solution of water in air : forgetting that this is little more than phraseology. What philosophy is there which has explained a cloud ? The mechanical one long pleased itself with its own childish solutions, hollow as the very bubble whence they were drawn : its vanity generated its credulity : for even thus do we persuade ourselves that the false is true. It will scarcely yet believe that it is wrong : while ignorant, or forgetting that it is passing its bounds and interfering with another science. Chemistry claims the right : but, if wise, it will abandon, for the present, what it cannot explain.

The cloud at least is tangible water : it might have been no difficult problem to float air in air, dissolved water in the atmosphere : we would gladly believe that it was not. But this was not sufficient. The stores of

water were to be transported in masses to the places where they were required : He collects it into masses, and He causes these to float in that atmosphere so much lighter than water, that His winds may lead them wheresoever they are wanted. Does any one consider the enormous weights which are supported in this marvellous manner, the seas of water which are thus suspended, and carried along like a feather before the breeze ? The torrents which fall from them will tell him what those weights are : it is a whole lake which descends from the heavens in an instant : a lake which, an hour before, was a hundred miles away, lighter than the thistle's down. Thus had it struck an ancient philosopher. " He bindeth up the waters in His thick clouds, and the cloud is not rent under them."

Nothing in the whole of this great process is explained. The cloud was formed from dissolved water : why does it not dissolve again ? or why not always, as it does sometimes ? It is the feeblest of substances and structures ; yet it is not injured by the most violent winds. The gale which in an instant tears the stout canvass, the hurricane which whirls a forest into the air, carry before them the tender cloud, unhurt : and though they may change the form, they do not destroy what they might have torn to pieces and dispersed in atoms. It has been commanded them that they abstain, as it was appointed to them to conduct the cloud to its destination ; and the storms are obedient to His will. What is this force of adhesion, this power of evading violence, in that which is without strength and without weight ? It may be electricity ; but it is still the power and the hand of the Creator. It is one of the miracles of nature : and it is but through its frequency and famili-

arity that it is not truly a miracle. Had it occurred but once, it would have been this : and it does not cease to be a wonderful exertion of power because it happens daily.

The cloud falls in rain : the cause may, again, be electricity, but we are as ignorant as before. All is marvellous, and all is unintelligible. If the winds transport the clouds as they list, so does the rain fall as it chooses, and no one shall say why. It is above us and around us, yet it will not descend : it is solicited, but it passes by. What, who is the agent in all this ? It is not chance : for even amid apparent caprice, the results are too certain and the good effects too steady. If any where, it is here that we ought to see His hand, since we can see nothing else ; no secondary cause, no deputed power. What physical power indeed could have been deputed to perform all that is thus done on the earth ? Electricity, change of temperature, anything which science chooses, might produce the single effect : but how is the whole chain conducted, and all the results ruled ? Can a physical agent be conceived, acting thus irregularly, never acting twice alike, yet ever producing the same great average effects ? Physical agents, under laws, are regular in their actions : for regularity is implied in the very proposition. The mechanician finds no difficulty with the laws of gravitation and motion : but no mathematics can conceive established laws to govern the rains. It may not indeed be impossible, but assuredly it appears impossible : and if it be, then does He himself, with His own hand, direct the clouds and the rains ; as He directs gravitation by that same hand. If the one is a regular force, or action, it is because regularity was necessary : but the action is not

the less His. The other is an irregular one, because such irregularity was probably useful, possibly indispensable : and still more therefore should we refer it to Him and His direct interference. Yet we object to this solution in the latter case, even when we are willing to admit it in the former : and why, but from the unworthy dogma, that conduct like this would be a personal and minute interference, and that the Creator does not, or ought not to govern in His own works and world.

The clouds are raised from the sea in a tenfold proportion compared to the land ; but in this proportion they do not fall into the sea again. Whether the efficient cause is here also to be sought in electricity, we can at least see the reason, and why, above all, they seek the mountains. The land was to be their destination ; for their office was to bring food to the vegetable world. The declivity of the mountains demand also a larger supply, since the water cannot there rest : while to them, further, is it committed to distribute the streams to the lower lands, as the heart of this vital circulation. Everything is arranged accordingly : the end is obvious, and the contrivance perfect.

The Creator has entrusted still more to the clouds : ever attaining many useful ends by one contrivance. They are a veil which He draws between the sun and the earth ; and who can doubt that this purpose was contemplated in their permanence, in their property of resisting the solvent power of the atmosphere ? We may sometimes complain of the evil, but we must not forget the good. All know the personal advantages which we so often derive from this arrangement : by the traveller of the African deserts at least, they are fully estimated. But all do not know that thus is vege-

tation fostered, and the imminent death of the tenderer plants prevented, by the check thus given to pernicious evaporation : and even less, possibly, is it known, that in this manner is the heat of the earth preserved under a similar check to the power of radiation.

It is nothing that the bountiful Father of all has rendered beautiful that which was useful, and also necessary ? has He not done this throughout all Creation ? The landscape of the sky, if I may use such a term, forms no small portion of the beauties of external nature. In itself it is a picture ; and it is indispensable to the picture beneath. Where all is for ever the same, the restless and various sky is an ever shifting and ever new picture, a perpetually changing landscape. We need not travel to seek fresh ones ; for they are brought to us hourly, and never yet were two alike. In form, in colour, in combination, the variety is endless : and if, full often, it exceeds all which the inanimate creation can produce, some beauty is never wanting. Nor are this variety and this beauty limited to the sky alone : for to the clouds, to their lights and shadows, and colours and forms and motions, has it been committed to change the face of the terrestrial landscape itself, and thus to produce, here also, those incessant variations which they cause in the heavens. And like the liquid water, they are the life of the landscape, as they are the living principle of the sky ; life itself. Far more indeed than water, since they are seldom absent, and never absent long. This is their beauty, exceeding all their other beauties ; this is their essential charm. The clouds and the ocean, these are the sufficient landscape : in motion or at rest, they are pictures which never weary, as they are pictures to which there

are no bounds : and it is to them we owe the life and the spirit of the unmoving inanimate landscape of the earth. The sympathies of man, of life, are with life : he feels the power of that secret which he has not investigated : and it is in their motion that he feels what he knows not how to explain, the tie which draws him to a living creation, to that universe which a soul inspires, as if it could sympathize with him, and, like himself, could feel.

But other and very different considerations demand notice ; and first among these is the statical equilibrium of water. By means of this has the Creator confined the ocean between the impassable boundaries of the land ; while, combined with its mobility, it forms those tides, on the wide utility of which I shall immediately make some remarks. Thus also is it the useful canal, the liquid highway of internal commerce ; as, in its mobility and gravity, it is the river of endless uses. Through its equilibrium, it is the standing well and the flowing spring ; as through this does man teach it to rise in new channels, far from its native sources, and, in other ways, to be a powerful servant for his mechanical wants. Applied by the Creator to far wider uses, its property of equilibration affords facility of motion to fishes ; as, without it, they could not have existed. Was this a necessary consequence of its structure, or a contingency belonging to the contrivance ? Even thus has philosophy desired to say, when laying down the law of the pressure of fluids : yet what more is this than to say that water presses equally in all directions because it does ? Such indeed is its language much oftener than it has perceived : but not in those terms. True : the law is such : but who was it that

made that law, and why might He not have made any other? There was an end in view : and He appointed that law when He created that form of matter, because; without this property, it could not have fulfilled His intentions.

There is yet more, of a very different nature, which water effects for the uses of animals. Its evaporation is the diminution of temperature. If this also be deemed a contingency, and not a beneficial design, the answer is the same. The utility is great, and the effects wide: He knew, and He caused. But I formerly pointed out the great value of this property as the regulator of animal heat: noting then also that beautiful system of compensation under which the excess produces its own correction. The compensating balance of a watch is not a more perfect contrivance, while it is a far easier one. In plants, it appears to produce similarly useful effects; as, in hot climates, it is a cooling process for the atmosphere also, and doubtless for the waters and for the earth: a compensation brought into action to check the power which excites it, and acting in proportion to the threatened injury. If indeed evaporation sometimes produces evil, as in the case of plants, this is, like the volcano and the hurricane, one of the contingent defects which pervade a creation much less than perfect: in which exceptions to good results are found everywhere.

I have always thought it unjust not to point out defects in creation when they are plainly such, as in the numerous cases of pain and evil, hereafter noticed: and even when it may be that they only appear defects to our imperfect judgments. In doing otherwise, we assume to defend or apologize for Him who wants no aid

or defence from us, or attempt to justify Him who is truth, through falsehood: by this also, or by an hypocrisy equally repugnant to religion, offending the plain sense of readers, and causing them to doubt respecting that which is really defensible. To point out what appears defective or evil, though we should be wrong, is the road to the investigation of the truth; teaching us to seek for the good intention and the good purpose, in everything, under the government of Him who cannot be otherwise than perfect.

If there are partial uses in ice, which we can see, this condition of water appears to produce a larger sum of evil. As water, it has become useless, and it even destroys the life to which it once administered. The freezing temperature, it is true, may be a necessity depending on the nature of heat and of the planetary mechanism: but it was not necessary that water, any more than alcohol, should have been solid at that temperature. If it is said that ice is useful for equalizing the heat of the globe, it is not easy to see how the needful ends might not have been gained by fluid water. Let us strive to find better reasons, that in this also we may be able to justify the ways of God in His creation.

There are many subsidiary and minor purposes served by water, which I need notice but in the briefest manner. They often bear a trifling aspect, from their nature or familiarity: they often appear contingencies or necessities, things not within the Creator's design. Yet we do wrong in thus judging, even under philosophy; since He surely knew of all the uses of what He has appointed: we wrong Him, and, in Him, ourselves, when we refuse to see Him in all that we receive or enjoy.

Water consolidates that soil which would otherwise bring on us all the evils of the sandy desert ; as those evils should direct us to see the good. I have elsewhere shown (ch. vi.) how it is the generator of soil from rocks, and moreover, the distributor : thus performing offices scarcely exceeded in importance by any of its numerous effects. It is not a trifling use, whatever it may at first seem, that it is the universal purifier ; while having performed its duty, it evaporates, leaving no inconvenience. It ought not to be deemed such, if, as has been said by a more than noted divine, “cleanliness is next to godliness,” and when that of the whole living creation has been so carefully provided for by a variety of contrivances. It is a property of the highest importance, productive of far more numerous and weighty effects than I can here note, that it is, in a certain restricted sense, the universal solvent ; that still obscure agent, even to the researches of modern chemistry, without which the operations of this power would be materially narrowed. It may be a familiar, but it is not a mean use, that its weight and mobility form great stores of moving force for man, widely applicable to his wants. Its powers of evaporation and expansion under heat, with its reconversion through cold, have proved to be of the greatest moment, since they have given us the steam-engine. If even this application of water was not within the designs of Providence, I know not well what He has done for the purpose of raising man above the surrounding animals : nor do I know why man was created the being of intelligence and ingenuity, if no correlative means were appointed on which that intelligence could operate.

But if I have no room to pursue those further details

which would not easily be exhausted, the ocean still demands some remarks, as being the chief mass of this element, and as a large integrant portion of our globe : while the present ones chiefly relate to the consequences resulting from its bulk and mobility, as its motions are the joint result of external forces and its own gravitating tendency to rest.

I have elsewhere shown that the presence of salt in the water of the sea does not prevent the putrefaction of its animal contents under death : as that notion is derived from a vulgar and inapplicable experience in domestic economy. At rest it becomes offensive or poisonous : and had this condition been constant, it could not have been inhabited as it now is. It would have been what a vitiated atmosphere is to the terrestrial races : and it would have been such, even without putrefaction ; since it is chiefly through agitation that it absorbs the air necessary to the respiration of fishes. And there are two causes which act in exciting its motions : the winds, and the attractions of the sun and moon ; while if neither of these act necessarily in producing the effects, we must here also infer a special contrivance of wisdom, for good ends.

There is nothing discoverable in the nature of air or water, to make us infer that adhesion, or friction, between the two, which enables the winds to ruffle the surface of the sea, thus laying the foundation of those waves which it afterwards lifts so high. There is no such adhesion between air and oil ; and hence the familiar effect of this substance in preventing the formation of waves. Thence must we conclude that while so useful a result as the agitation of the sea was intended, this property was conferred for that purpose. Upon

every theory of the winds yet proposed, the motion of streams of air should also be parallel to the horizon, at least in a very great proportion. But such currents could not have acted powerfully on the surface of the water : while, in reality, the winds are most irregular and intricate, as it is the descending streams which produce the chief effect : leading us similarly to presume that these motions were intended for this end, if for others also. The valuable consequences have been just noticed, and it is not difficult to see how they are produced. Dilution and dispersion do much : air is thus introduced to aid in the decomposition of the noxious substances : and clay and sand are intermixed with the water, so as to precipitate those ; while this last contrivance acts most extensively in shallow seas, and near shores, where the decomposing substances are most abundant. All this happens equally in rivers : and hence the utility of their turbid state, so idly the cause of complaint : while we thus see the futility of the alarms which ignorance and ill humour are ever exciting on this subject, especially in large towns. The Creator has not permitted that His great stores of this needful element shall be long or extensively corrupted, even by man.

If the other great cause of the motions in the sea consists in the attractions of the sun and moon, the primary effect of which is the production of the tides, the chief results which I am to notice are different from the preceding. Yet it might here again be said that they were unavoidable, not designed : a necessary part of the constitution of our globe, whence no special beneficent intention could therefore be inferred. The answer which I have already made is valid here, if ever it is valid : yet

some physical arguments are also producible, to prove that a special provision for tides has been made, in addition to that action of the sun and moon which may be admitted to have been unavoidable.

There could have been no tides approaching to the present ones, in elevation and power, had not the ocean possessed that very great, and long unsuspected, average depth which Laplace has proved to be necessary for this effect; amounting to nearly five miles. And we can discover no other purpose in this, since it was not required for the production of rain, nor the communication between distant lands. So far also from being needed for the inhabitants of the sea, these are unable to reside in depth infinitely less, for obvious and well-known reasons. It is remarkable also, that the depressions beneath the level of the mathematical spheroid should so far exceed the elevations above it: producing an irregularity far greater than that of the visible surface, for no other purpose but that of lodging a large mass of water. We can scarcely avoid believing that this was the real purpose, and the end the production of the tides; the more especially when the utility or beneficence of this arrangement is so palpable.

If this is one argument, the other consists in the disposition of the land bounding the ocean. This at least was arbitrary: while it is thus that the oceanic tides, of little value in the wide sea, are rendered effectual for their useful ends. But if we choose to consider the disposition of the shores as accidental, because of its irregularity, and their tides therefore as undesigned, we might as well form the same erroneous judgment respecting the elevations of the land, and view as mere

accidents, the mountains whose designs I have so fully demonstrated.

A specific intention being therefore inferred, to augment the power of the tides where that was most needed, and for special ends, it is barely sufficient that I notice the aid they afford in the purification of the sea. Their action is greatest in the narrow and shallow parts, or near the shores swarming with fishes and covered with plants: since it is in such places that a real stream, or an absolute transference of large masses of water takes place, from well-known hydraulic causes. But there is also entrusted to them the office of checking the descent of the terrestrial alluvia, for the purpose of extending the land, with the further one of distributing those beneath the water, for the same future purposes, and for the more remote ones that concern a new modification of our globe.

The more obvious and direct uses to man are numerous. Every navigator knows how much he effects by taking advantage of the tide streams, how often they supply the place of the winds to him. But the effect, above all, which is valuable to us, is that of producing ports and harbours, under a variety of forms and circumstances, where they could never else have existed. The Thames is the port of the universe but because of its tides: but the examples are everywhere. It is thus that commerce is brought into the heart of our inland towns; and thus can man build on the dry land, that ship which the sea will come and take away for him whenever he desires, with scarcely any exertion of his own. But I need not proceed on this subject: while it is sufficient barely to remind the reader, that but for the oceanic tides, enabling the Coral animals to raise their

works beyond the mean level of the sea, the island could never have surmounted it, except through volcanic agency.

Thus terminating those more important parts of the history of water which theological writers have almost, or entirely, neglected, I shall now do little more than hint at the few remaining facts which have been abundantly discussed. The advantages accruing to agriculture from the nonconducting property of snow have been often pointed out. So has that remarkable property in water by which it ceases to contract, and thence to augment in specific gravity, before it arrives at the freezing point, with that diminution of its specific gravity which it experiences on freezing; the former, in particular, presenting so remarkable an analogy, that we cannot but believe it a special exception made for as special an end. Both provisions, I need scarcely say, conduce to one great object, the easier restoration of ice to the state of water. Had water at 40° continued progressively to contract and sink, it would have frozen at the bottom: had ice not floated, it would equally have lodged there; while it would then have long evaded the action of the atmospheric heat.

To end; it were fortunate if on all these subjects, the reader could supply all that the writer must omit, and the reflections rather than the facts. But creation, as the visible word of God, has not been very often considered a fitting study for man: while if He has not been connected with His own works, thus too perhaps has He been neglected. And if He has been sought elsewhere, even Christian charity must admit that He has not always been sought in love, and in purity of heart, but because of the scope afforded for the display of our evil passions.

Creation affords no grounds for theological hypotheses and contests : and it has always been easy to say, what ignorance too may have innocently enough said, that the pursuit was purposeless as to God and religion : while it has also been found easy to maintain, that He would operate all that was needful, on the heart of man, without study, and without the labour of thought : a doctrine most consolatory to those who have wanted will, industry, or ability, to study His ways and to learn to know Him as He is.

CHAPTER XXXIII.

ON THE ATMOSPHERE.

CHEMISTRY has now made us so familiar with the gaseous forms of matter, that even philosophy forgets to note the wonders which would have excited its astonishment, or its incredulity, had the whole been displayed to it in the days of its ignorance. The enormous mass of matter contained in the atmosphere is indeed still nothing to the ignorant: they breathe without knowing what, or to what end; they can neither feel nor see nor taste nor smell this apparent nullity: the barometer is to them but a weather-glass; and of that which fills their sails and agitates their trees, they simply know that it is wind. Yet it is a strange substance. To die for want of what can neither be seen nor felt, smelt nor tasted, to die in the midst of other equally invisible and insensible substances, are facts which might excite wonder or curiosity. It might excite wonder to feel that we fall before the force of that Invisible which in the next moment is nothing: to witness the irresistible power of that which can neither be seen nor touched: to be convinced that there is around us a dormant spirit which need only be roused, and by powers which we can neither conjecture nor anticipate, that it may sweep us from the earth. Yet between knowledge and ignorance there is here little difference: such is the effect of familiarity, or such it is not to reflect.

I need scarcely say that the air around us is a chemical compound, and of oxygen and azote chiefly, since the school-books of chemistry have made this, and more, familiar. I need not say that it is a ponderable substance, and a weighty one, when a cubic foot weighs more than half an ounce; that it invests the earth to an altitude which, under different views, has been estimated at fifty miles, and at more than three hundred; that its pressure is equal to fifteen pounds on a square inch, and that the total weight of the atmosphere has been thus computed at 5,000,000,000,000,000 of tons. Every one knows these things, or every one can find them, with the evidences on which they rest. Nor need I say that its two chief ingredients can exist in a fluid, and in a solid state, in other combinations, and that chemistry believes them capable of existing in each state, separately, or united, under a possible deprivation of heat, or under such a pressure as may be imagined within the depths of the earth. And thus barely reminding the reader of that which is now universally known, I need but notice again the hypothesis which desires to explain the formation of the atmosphere from a chaotic globe, as it trusts to explain the production of water in the same manner.

All this knowledge, and more, must be presupposed: it is the object, here, to point out those circumstances relating to the atmosphere, which may bear on the purposes of this work. And, in a general view, the most remarkable fact is, the great variety of ends attained through this contrivance: evincing, as in the case of water, that kind of wisdom which, with little apparent effort, succeeds in accomplishing numerous ends, of the most discordant or different natures, by limited means. This is

the simplicity of the Creator's proceedings, under a new view: that real simplicity which is so often overlooked where it exists, and so often assumed in consequence of an hypothesis, where it is not found and would not be applicable; where it would not honour the wisdom of the Creator, but where it flatters the vanity which assumes to know what it has not investigated, and to dictate to the Being who conferred on it the power of criticising or regulating, as it would fain believe, the designs which it will not study or cannot understand.

It may strike the reader more strongly, if I commence by enumerating the variety of effects produced by the atmosphere: for which it has been created, and its properties appointed.

As a chemical substance, it is that perpetual agent without which animals could not exist for an instant: and, if in a different manner, it is not less essential to the life of plants, from the vegetation of the germ upwards. It is active, moreover, in that decomposition through which all organized forms are returned to their elements; as it is thus also a great laboratory or stock of materials, on which new organizations draw, that the round of life, under temporary and ever renovated existences, may proceed. Being the food of respiration, it is also that of fire, and is thence indispensable to the production of artificial heat and light. Under properties partly chemical and partly mechanical, it is the medium, or, with other powers, the joint cause of evaporation, and thence of all that is consequent on this in the circulation of the waters of the globe. Through powers which we cannot yet assign, it is an agent for the production of heat from the sun's rays: and from a constitution similarly unexplained, it effects the most

important purposes in diffusing, and thus, as far as vision is concerned, augmenting, the light of that body ; while, through its power of refraction, it serves other important purposes as to both light and heat. As a mechanical gas or aëriform fluid, it is the medium of support for the flying animals, and the resisting fulcrum of their motions : while when in motion itself, it becomes a mechanical force for the uses of man. Under actions which have not yet been ascertained, it is the medium of sound, and probably one of its causes : while lastly, as a chemical body, it is concerned in actions and combinations so numerous as to pervade the whole range of chemistry.

Even thus briefly stated, these are extraordinary effects, in magnitude and variety, to be produced by a substance so apparently neutral or powerless : seeming to be nothing when at rest, and, when in motion, but feeble, since it requires large masses to act with energy, or failing this, great velocity ; while, not betraying itself to our senses, its apparent neutrality as a chemical power is even more striking. Nothing can well be conceived more simple than the body by which all these diverse and great effects are produced, though we conjoin its chemical and its mechanical nature. The former is a simple combination of two elements : and these suffice for every chemical action which it performs : under the latter, it possesses a definite weight, is subject to the law of universal pressure and equilibrium, and is endowed with an equivalent elasticity : while adding expansibility under heat, we have all the properties through which it is the mechanical agent that we see. The simplicity of the celestial mechanism is beautiful : but I know not that it exceeds that of the atmosphere, when

the multifarious effects which it produces are considered. And this is wisdom united to power.

Why then has it been said by a noted writer on natural theology, (need I name Paley?) that "the elements" do not well demonstrate the attributes of the Deity, that the facts are too abstruse for general readers? There is nothing in creation which affords clearer and brighter evidences of Him, nor is there any difficulty in the facts or inferences, if clearly stated and rightly drawn. The teacher has no right to complain of the pupil whom he knows not how to enlighten, nor to excuse his own want of knowledge and power by throwing blame on the understandings of others.

To commence with the chemical uses of the atmosphere, the most conspicuous is its necessity to animal life. Though food may be the fundamental source of nutrition, and the stomach the prime organ for this purpose, all this preparation would have been in vain without air and without the lungs: it is but one-half of the circle of nutrition. To us, this appears a circuitous process: but we must at present be satisfied in seeing, that, having been appointed, the result is perfect. I need not repeat the familiar details: the more, that we do not understand the process carried on in the lungs. Indispensable as oxygen is, insomuch that it seems almost to have absorbed the whole attention of physiologists, the other ingredient, azote, cannot but be equally necessary. That so abundant a portion of atmospheric air should be a mere diluent of the other, is improbable, as implying an awkward chemistry in the Contriver: while it is only through its appropriation that we can account for the large quantity of this substance in the vegetable-eating animals, unless indeed we have assumed

that to be a simple element, which is a compound ; as is not improbable.

My purpose however does not demand the discussion of these difficulties ; suffice it, that in the sense in which I may safely use that word as indicating supply, the atmosphere is a great laboratory or store of food for animals, just as water is for vegetables. And, as such, it surrounds them everywhere : ever brought to them, and ever received, without exertion, and almost without consciousness. It is even present in the ocean, for the same uses, as I have recently shown, and, as continually consumed, for ever renewed. To this end, among others, does its mechanical constitution also tend, so admirably are these different properties arranged : since, by its pressure and elasticity, it finds its way everywhere, and can scarcely be excluded without much contrivance.

The atmosphere is not less necessary to vegetable life ; though our ignorance of its chemical action is even greater here than in the case of animals. It is not all, that it is the repository of carbon in the shape of carbonic acid, and of gaseous water, to supply them with food ; and that it is the receptacle of the airs emitted through their internal chemical actions. For some reason they require oxygen, as animals do, and they die without it : while this is especially remarkable in the germination of seeds. But, for the present, we must acknowledge our ignorance : as this depends, it is probable, chiefly on that of the actual elements and their combinations. Yet we can still admire the beauty and simplicity of a contrivance by which both classes of life are supported, if in different ways.

In the last chapter I showed, that in decomposing water for their food, plants emitted oxygen ; and have

thus far anticipated the great question of the repair, or renewal of the atmosphere. But there is more concerned on this subject, though our knowledge does not yet enable us to explain the whole of the process adopted for this great end. The respiration of animals furnishes carbonic acid, corrupting the atmosphere as it is necessary for their existence. But that is the food of plants: and thence it is probable, although we cannot yet satisfactorily prove it, that there is a perfect circle of mutual support and dependence between plants and animals, in this case as in that of food; the former furnishing oxygen to the latter, as this class, in return, supplies it with carbon. The beautiful simplicity of such a contrivance makes us also desirous that it should prove rigidly true.

But in whatever way the integrity and quantity of the great laboratory of the atmosphere is preserved, under the consumption of its oxygen especially, not only by animals, but by combustion, and by the endless chemical processes for ever going on in the earth, it is for ever repaired, since it is ever sufficient for its various duties. We have no reason to think, from experience, that it is now different in quality or quantity, from what it was at the creation: while we ought also to infer this, from the general analogy of nature in the continued perfection of the celestial system and the unvarying round of living organizations. Hitherto, the Creator has not communicated to us the whole of His secret workings towards this great end: but the day will come when in this also we shall have learned to admire with understanding. Similar difficulties seem to attend the consumption and the repair of the water of our globe, if indeed that consumption be

replaced : while I reserved that question, from the preceding chapter, to this place. It is consumed, both by organic and inorganic bodies ; part of it being solidified, while the remainder becomes air, and the apparent cause of atmospheric reparation. Chemistry does not know how it is replaced, or whether it be restored : though it can see that much at least of what is solidified in plants and animals is returned to the atmosphere in an elementary form, on their decomposition ; thence possibly to become water once more. And if there be a portion permanently solidified in the inorganic substances, as there must also have been, in former times, in coal, such is the enormous bulk of the ocean, that a supply might well be afforded through uncountable ages. Chemistry may perhaps hereafter show that the repair is perfect in this case, as in that of the atmosphere : but whether that shall happen or not, we may smile at the fears which have anticipated the final consumption of all the water of the globe, as at the hypotheses proposed to prevent such a catastrophe ; while if those persons have imagined that the waters of the ocean were gradually diminishing, geology can now correct them, by demonstrating the sources of this deception, in the formation of new lands, and in the vacillations of the level of the solid earth. I may proceed to the agency of the atmosphere in the decomposition of organized bodies.

On the departure of life, the organizations are sooner or later reduced to their pristine elements, or sub-elements, by the powers of chemistry. Whatever the water and the earth may receive, or whatever the agency of the former may be, the atmosphere is the final receptacle of all which becomes aëriform ; and this constitutes a large portion of the animal material at

least, as, under certain circumstances of heat and moisture, of the vegetable one also. The presence of oxygen is also essential to this process; and thus the atmosphere is a chemical agent, as it is the receptacle of that which it has assisted in decomposing. But if the atmosphere here performs one of its appointed chemical duties, so does it exercise a mechanical one for the same general ends. The animal and the plant have been converted into air, ready for new combinations, and to revive in new organizations. That which aided in the office of destruction, and which has also received these materials, serves to transport them wherever they are wanted; and thus is the atmosphere a storehouse of supply for organized beings, in a simpler and stronger sense than as it is the medium of respiration. It affords prepared food: and if, in this process, the nutritious matters thus produced unite with water and with earth, it is but extending the circle of these chemical actions without diminishing our admiration of its beauty.

All these are great, enormous chemical operations, intrusted to the atmosphere and conducted by it; but they are far from the whole. As the power and the substance through which water is converted into air, and retained, transported, and applied where it is wanted, it is almost a more wonderful and universal agent: while, here, both its chemical and mechanical properties are called into action. But this part of its history having been examined in the preceding chapter, I may pass on to the most splendid at least of its chemical agencies, in the production of light and heat, though I must shortly treat of those more fully.

The atmosphere is the great engine of combustion; being rendered such by that element, oxygen, through

which chiefly it is a support of animal life. Without its presence and action, fire and life are equally extinguished. This is another example of simplicity in contrivance; since we can see no natural or necessary connexion between these two. Nor, however chemistry may have flattered and deceived itself, in overlooking the most palpable objections to its hypotheses, can we yet solve the mystery of the production of light and heat through that combination of well-known elements which takes place under a certain elevation of temperature. The same inflammable substances combine with oxygen at lower temperatures, without those effects: no reason can yet be assigned why the result is not the same in all cases: except indeed that which philosophy is too apt to treat with disdain, and with which mere science ought not to be satisfied. He designed to produce fire and light from other sources than the sun, and for great ends, including, very strikingly, their uses to man. He willed the means; we are bound to investigate those: but piety can still repose in the First Cause. But while chemistry cannot yet discover whence the light and heat come, I need not here discuss this or the other difficulties which beset this subject.

It is more interesting to note that result of combustion which concerns the atmosphere as a storehouse of food for vegetables, while this is also among the limited objects of the present chapter. The far larger proportion of the solids which fire consumes, become air and water; while that air, carbonic acid, returns carbon, in the most manageable form, to reproduce, under new lives, the beings from whose destruction it had originated. The forest itself may vanish from our eyes:

its restoration may seem hopeless; but it still exists, under a fitter form for use, and is again called on to circulate in the same never-ending round. Through this agency of the atmosphere, even the long-reposited remains of a far distant vegetable world are converted into the living plants of our own days. Man desires to extract heat from the buried rocks of coal; and having performed this office, they are dissipated to the winds, and lost, apparently for ever. But He who thus laid them up, takes possession again and returns them to the earth, while the invisible air becomes, in His hands, a new creation of plants to clothe the earth with life. In this way, as in many more, ought we to contemplate the great laboratory of the atmosphere; though these vast offices are scarcely conjectured but by chemical science. It is well said that nothing is lost. The drop of water which is spilt, the fragment of paper which is burnt, the plant that rots on the ground, all that perishes and is forgotten, equally seeks this great element, and all is there preserved, and thence daily returned for use. The circulation of the blood is not more sure; nor is it more artificial, if the artifice is of a more obvious nature.

Such are the greater chemical offices of the atmosphere, but they are far from the whole. On those however which remain, I must be brief; since I have elsewhere noticed some, while others relate to chemical facts, of limited general interest. Among the former is the action of the air in decomposing rocks, so as to convert them into soils: while it is partly through this that the mountains are also lowered, with those great results, in the formation of new lands, which I have elsewhere described. This too is an enormous power consigned to so apparently feeble an agent; as it

is a further instance of that simplicity through which the Divine wisdom attains its numerous ends. In the latter set of actions, I may notice the oxydation of metals, the formation of acids, and the changes effected on such compound inflammables as the oils and resins ; while I must refer to the science of chemistry and its writings, for what would not be here admissible. Yet, if I note, that through this agency, the threads of the spider and of the silkworm become the tenacious fibres we know, that hence the paint which embodies the conceptions of the artist and protects our internal architecture, it may excite the reader's curiosity to pursue this subject through the whole of its interest and utility, and thus to form for himself a more impressive notion of the wisdom and power which accomplish ends so numerous, so various, so great, and so useful, in so simple a manner.

If natural theology had, hitherto, thus limited itself, we now see that the powers and uses of this great element are not to be studied in its mechanical properties alone : though I must proceed to notice some of those facts under these, which, as often brought forward, display less of a new interest.

I have already enumerated the well-known facts, that, like water, the atmosphere tends to a statical equilibrium, and that its elasticity is an effectual and perpetual counterpoise to its pressure. Thence flow those valuable results, especially in the animal organizations, which are familiar to every one, as other needful and extensive effects are produced in other parts of nature. It is easy to term this a law, as in the case of the statical equilibrium of water. It is indeed a most indispensable one : but as I formerly remarked (c. 23.) there is no evi-

dence of a physical necessity for this law, more than for the other : or there is nothing in the constitution of the atmosphere on other points, whence we must infer that its elastic property should be a counterforce to its weight. Could mathematics even show how this is effected, this would not interfere with the important moral conclusion: while, at present, we must view it as an arbitrary law, ordained because it was required. The same is true respecting the regulation of this elasticity through variations of temperature. It was indispensable for great ends in the atmosphere, that, under the same bulk, a smaller quantity of matter, or an inferior specific gravity, should counterpoise a larger, or a superior one. No one can say that certain increments of heat must have produced corresponding elasticities : nor indeed have we even ascertained the exact nature of the facts, or the law in question. Thence we must return to the same conclusion. The necessity lies in the will of the Creator : and He thus willed, because thus He resolved to accomplish certain purposes.

The first great mechanical office of the atmosphere which I may notice, is that which is connected with the production of heat from the sun's rays : but while the question is difficult and the mode disputed, I have said whatever was needed under the title of Heat. Under that of Light, I have equally pointed out its value in the extension, or multiplication of that power : and if it is for the sake of bringing all the powers of this element under one view that I indulge in some repetition, I may here observe, that to this we owe the light which we receive during the absence or interruption of the sun's rays, with that which is never absent in the darkest night, and is of so much use to the nocturnal animals.

Both of these are great offices ; and the latter, especially, is one of the highest importance : while we must here again admire the resource which combined this power of reflection with all the other properties of the atmosphere, and, above all, with that transparency which was essential to the transmission of light. To us, these would appear irreconcilable qualities and actions: while we cannot even conjecture how both ends are attained, and become the more bewildered the more minutely we reflect on them. Transparent, to transmit light, and reflecting, in order to multiply it, the atmosphere has also the further power of refracting it : thus prolonging the presence of the sun's light and heat, and, by another beautiful and simple arrangement, under which cold augments this quality, effecting this most completely in the very places where the necessity is greatest.

Little as we know of the mode in which sound is produced and propagated, the atmosphere is essentially concerned in both, while the immediate causes must appertain to its mechanical laws. It is useless to give the common solutions, for they explain nothing: as even the assumed facts are not themselves proved. Thus much however is interesting, as relates to the contrivance and the final cause. Motions, termed vibrations, in solid bodies, produce sounds, and also conduct them through those bodies, with an intensity and rapidity which seem to bear some proportion to their density and elasticity : while the same occurs in the liquids and the aëriform fluids, though natural philosophy has not yet arranged the facts so as to lead to any accurate general rules. Reversely, no sound is conducted through a vacuum : as, of course, none can be produced in nothing. It would have been a rational *à priori* conclusion, that

the conducting power should bear a regular proportion to the qualities of these several bodies, as just named, and that the atmosphere should thence be an indifferent conductor. But it was necessary that it should be a good one, and it is such : while if we refer this to its elasticity, we do not explain an action but use a term, and while it is only to say, that the elastic property of the atmosphere has been created for this, among other duties, and that, as is common, many ends are attained through one arbitrary contrivance.

This then is another property of the atmosphere, distinct from every preceding one, and even from those mechanical ones with which it appears most connected : since the great movements of transference to which it is subjected, interfere very little with those motions through which it transmits sound, and, in the most important particular, velocity, not at all, as far as we yet know. Natural philosophy, as usual, labours to explain, and explains nothing. Why record or examine its hypotheses ? When it can explain in detail, instead of using terms and phrases to console its vanity, it will be understood if it is intelligible, and may be criticised if it is otherwise. At present, we know, at least, that the atmosphere does move in this case, since it excites the motion of a solid body, yet in that single instance only, of concordant and distant strings ; but the theory of undulations does not fail one jot the less, when we attempt to explain by it the non-interference of crossing sounds, the contempt of these supposed motions for wind, the reflections of sound, and far more than the varieties of “ timbre ” in what relates to musical instruments. It is a singular constitution of things : and, judging as we are compelled to do in every case, we ought to deem it a great effort of

contrivance and power, because of the difficulty we find in explaining it. It is for this reason, as I have before said, and for no other purpose, that I have, here and elsewhere, pointed out the ignorance and pretensions of natural philosophy. It is evil enough, if in truly assigning the laws of nature it takes off the attention from Him who appointed them : we need not also permit ourselves to be diverted from contemplating the Deity by every idle hypothesis which it chooses to fabricate ; if much oftener from habit and from vanity, than because it will not look to Him as the Cause.

I do not know whether to call the non-conducting power of the atmosphere for heat a mechanical or a chemical property ; so ignorant are we as yet, of the exact nature and laws of heat. In either case, while I have necessarily treated of it in the chapter on that subject, it must be here enumerated among the remarkable properties of this great element : the whole, even thus far, forming a mass and a combination, the number, the variety, and the influence of which cannot fail to have struck even the informed reader who never before saw them under that approximation which science cannot follow, but which is essential to a work that must ever appeal to the First Cause.

What I have thus been pointing out as to the atmosphere, relates to the refinements and obscurities of mechanical power : to actions which must, either from analogy, or by dilemma, depend on mechanical laws, though we cannot assign their exact nature or action. What follows is comparatively simple, and is in general sufficiently easy to understand : though, on some points, great difficulties yet remain as to the causes of mechanical actions which, in themselves, can be reduced to well-known rules.

The weight, or pressure of the atmosphere, be it whatever necessity it may, is a great and active power ; or is at least rendered such through that beautiful system of adaptation, under which the properties of one body are fitted to those of another, or checked by them, so as to produce a desired effect. This pressure is the cause of the liquid state of certain bodies, which, without it, would have only a gaseous existence. The fluid is calculated for the weight which it has to bear : though under this, as a prime fact, perfect cases are only found in such artificial compounds as the ethers and some other fluids in chemistry. In the most important one of all, that of water, this effect is partial, but the weight of the atmosphere is a powerful and a valuable check on its evaporation : while we cannot doubt that the volatility of this element under heat has been regulated to meet its pressure, or, that the latter has been adapted to the former, so as to produce the precise effects that were desired under all circumstances. And this is another of those beautiful adaptations or balances, which, barely noticed there, might have found a fuller place in the chapter on that subject, but for the confusion or repetition which would have ensued, as might many more which I have noted in their natural places under science, as opportunity served. I need not extend the scientific portion of these remarks so far as to show the relations between this pressure and the varying conditions as to heat and the constitutions of fluids, as they affect the production of fluidity throughout various bodies : and it would too much prolong remarks of detail, to point out how the weight of the atmosphere restrains those evaporations which would speedily destroy the animal and vegetable structures.

Every one knows what the vacuum of an airpump can perform, and what is the effect of dry air on living organizations: while if the latter belongs to the chemical constitution of the atmosphere, the result is the same under the mechanical one. Let the reader turn his eyes round on creation, and then apply the principles laid down, whether in this case or in any other: for by this will he learn what no reading could teach him, were it possible for a writer to make an encyclopædia of such a work as this.

In the same way does the pressure of the atmosphere prevent the disengagement of air, of whatever nature, from those fluids with which it is united, and, if under chemical combination, so feebly, that without this mechanical force, that union would be dissolved. The importance of this leading fact is far greater than may at first appear; since thus only is the sea enabled to be a medium of respiration for fishes. In the animal organization, moreover, there is air, sometimes separate, at others loosely united, which nothing but this pressure restrains within due bounds, though on the details of this I cannot here enter. And I shall only further remark on these bodies, that however insensible the weight of the atmosphere may be, in consequence of the beautiful laws of its equilibrium already noticed, its effects on those organizations are most important, while they have been constructed under a respect to this pressure, according to the universal system of adaptations.

The weight, or pressure of the atmosphere, under various circumstances by which that is effected, is applied to far more splendid ends in the regulation of those motions and effects which rank under meteorology. These circumstances must be sought in the variations

of its specific gravity, under differences of altitude, through dissolved water, and through heat, in variations of its elasticity from the same causes, and probably in other affections of its condition dependent on electricity: yet though I name these under its mechanical properties, its chemical ones are too often engaged to permit of any real separation. But our present knowledge does not allow us to explain these powers and actions, and apply them to the effects produced: and thence I must be satisfied with pointing out some of the most important facts: while if even the most perfect explanations could be given, scientific investigations and statements are foreign to the object of this work. The motions to which I here allude consist in the insensible circulation of the atmosphere, and in the winds: but though apparently under the laws of mechanics, this science has had but little success in explaining them. Fortunately, the conclusions of natural theology can be rendered independent of accurate scientific knowledge; while in giving a brief sketch of the atmospheric motions, I may perhaps succeed in displaying the attentions of the Creator in a manner somewhat more minute than I have already indulged in.

It has been said that the winds were inevitable contingencies arising from the very existence of an atmosphere and the mutations of temperature. But this belongs to the negligent philosophy of former days: it is little creditable to the present that it should continue to be repeated. If the influence of unequal temperatures on different portions of the atmosphere be the causes of wind, there should be no difficulty in demonstrating that in most cases at least. But I shall immediately show that this is not, and cannot be, the universal cause: and

though the unknown causes should be found, and proved necessary ones, the winds are, to us, from the will of God; while we cannot here perceive even that species of necessity which exists in the case of the tides: seeing nothing but the great and mysterious Hand which moves all.

The alternating land and sea breezes of the tropical regions are indeed produced through inequalities of temperature, and whether contingent or not, an effect so beneficial must have been intended, if the Deity intends any good to His creation. In ancient language, the colder air of the sea rushes in to fill a vacuum: in accurate philosophy, the air which is heated by the land ascends, under the lateral pressure of that which is colder, and which thus supplies its place. The same general explanation suffices for numerous other cases of winds, in all climates: as it also does for local winds occurring on the land, where its different portions, from unequal elevation or other causes, differ in temperature. How far the same theory explains the trade winds, I shall inquire hereafter: but it does not account for the variable sea winds beyond the tropics, far less for the more difficult cases which occur near land, and even some of those which are found at sea. A hurricane and a typhoon remain as inexplicable as the simoom of the desert: no possible theory of temperatures will explain these. In spite of the explanations given, the occurrence and the shifting of the monsoons and other periodical winds are still obscure, unless we can be satisfied with vague, general causes: and this is even more true of our equinoctial gales; since no one who thinks accurately can believe such effects to arise from slender differences in the position of the earth as to the sun.

The equatorial line on a paper globe may have a magical appearance: but there is no magical influence in a space of one or two degrees, here, any more than in any other portion of the intertropical belt. Under a gradual progress, there is no sudden and adequate change of temperature: in philosophy, equinox, or date, is nothing.

But if these are simply unexplained cases, what shall be said of those which oppose this theory? By means of the winds, the Creator transfers to us the summer temperature of warmer regions, that He may diminish the rigours of our own winter. Did the hypothesis assign the cause justly, this could not be: we could have but a north wind. Yet it arrives from the south, as it also passes us towards the polar regions, carrying thither, for the same ends, a tropical temperature. It is a river of warm air, and near the surface of the sea also, traversing thousands of miles to mix itself with a frozen and heavier air, not even ascending, as it ought, to displace a colder air above it. Had the Creator been tied down by the hypothesis, He could not have done this. In the old language, it is the vacuum rushing in to fill the plenum.

But this is not all. If no theory has explained the cause of a squall at sea, of squally weather, of the radiating winds which often attend a cloud, of a whirlwind, and much more, there are other and simpler cases which remain equally obscure, and even contradictory to the theory of unequal temperatures. A ship is becalmed for weeks between the tropics: why does not cold air arrive to supply the place of the warmer air which is ascending? Whence are the curvilinear winds, and whence the horizontal, and opposing or diverse winds, which occupy different strata of the atmosphere,

and often with very different velocities and at different temperatures? Being in contact, why do they not mix, to equalize each other's heat? My own observations being responsible for what follows, I may also ask what cause can produce a horizontally undulating stream of wind in the midst of an atmosphere at rest, and on what theory can opposing streams flow with great force at the surface of the sea for many hours, and in contact; touching without interfering? It is a minor difficulty, to find a strong breeze three or four miles in breadth, and assignable for many miles in length, in the midst of an atmosphere at rest, so that a foot would define the boundary of the calm; it is a much greater one to have seen two such streams crossing each other at right angles, and thus lasting for many hours. Such winds cannot be hastening to fill a "vacuum," or equalize a density: even in the first and simplest case, the surrounding atmosphere would not then remain at rest. And what explanation can be offered of a powerful breeze occupying many hundred square miles of sea, for a whole day, yet leaving one spot, a few yards in diameter, in a state of absolute calm all that time?

These are facts enough. I do not adduce them for the sake of proving the falsity of the popular theory, or our ignorance; but that I may leave others to infer whether He does not hold the winds in the hollow of His hand, and distribute them for the benefit of His creation; and through agents too obscure, and apparently too various, to be referable to those things which we are pleased to term necessities under creation.

If the equalization of temperature through the winds, as one of their great uses, consists in the case just alluded to, in the transference of warm air to a colder region, the

reverse process, or the introduction of cold air to a heated spot, is that which occurs in every insular and maritime situation, as well as in that of the intertropical shores already noticed : while the same takes place on the land, under a great variety of circumstances. Hence, familiarly, the equable temperatures of islands : as the reader's knowledge must supply the facts and illustrations which I need not : while, in this, he will find other reasons than the more obvious ones, for the present distribution of the sea and land, and also for the inequalities of the earth's surface.

Another great advantage derived from the winds, is the equalization or restoration of the purity of the atmosphere, corrupted, or changed, by respiration, or other chemical actions. And even without absolute wind, this end is gained by means of its mobility, and through those incessant and nearly insensible motions, of which the causes are not very obvious, whatever effect may be produced by inequality of temperature. It is further probable that the same purposes were in view, in that property through which different gases mix with each other when approximated, even without chemical union.

But the distribution of the rains is one of the most important offices entrusted to them : and it may perhaps be viewed as the great reason for those unknown laws which govern the movements that changes of temperature will not explain. Had there been no other causes, the earth must have wanted its fertility : since the transportation of the rains cannot be explained in this manner. The ocean is their great source, and hence chiefly arrive the ready-formed clouds, or the overcharged air which is to produce them : once more, it is

a current of warm air penetrating into a colder mass : being even admittedly so, since thus does meteorology explain the precipitation of the water held in solution. Be the cause what it may, it is not at least that which produces the sea-breeze of a tropical shore, since the circumstances are reversed. That which the Creator designed to do, He effects : but science is still ignorant of the mode, and must at present rest in the conclusions of an ancient philosopher : “The clouds are turned round about by His counsels, that they may do whatsoever He commandeth them upon the face of the world in the earth.”

If it be considered a subsidiary purpose, it is a most important one to man, that the winds are the great agents for his communication throughout the globe : while if the temperatures of remote climates are thus equalized, so are their productions. The winds are commerce : the highway of nations were in vain without them. Had they done no more than this, their office would have been one of a splendid utility : that this use was in view, when the productions of the soil were lavished in wasteful superfluity on one spot, and withheld from another, who can doubt ? And he who considers what commerce has effected for man, not in this only, but in all that regards him as the tenant of a moral and intellectual world, will not believe that this use of the winds was not also designed.

The caprices of the winds are the hourly and proverbial subject of remark, and, not seldom, of thoughtless complaint. Even for these however, there are causes, though we know them not ; and in every caprice or change there is a benefit for some one. Had man possessed the power which fable has sometimes assigned

him, could he have regulated them so well ; capricious and causeless as they may seem ? But there is a peculiarity in the distribution of even these apparently capricious winds, which marks a design in the midst of all this seeming disorder. In the great Trade wind, the design is obvious : it circulates round the globe where the ocean is widest, and is thus the great aid to the chief highway for the most distant communications. It is always to be found where it is wanted ; while the steadiness of its declinations from the fundamental course, renders it, in those parts, not less useful. Within the range of those several winds, the navigator requires little which he cannot accomplish through their aid ; while where they become evanescent, the very shores which he desires to reach or to navigate, begin to act on them and produce the variable and local winds to aid him. If this be chance or contingency, to the same causes do we owe the tides of the narrow seas.

Why should not the trade wind and its dependencies have extended much further ; even to the Polar circles ? The common theory of these winds cannot answer this question. Had not experience taught otherwise, it would have said that they did. But thus might our own seas have been subject to a northerly wind, as steady as is the north-east at lower latitudes : thus at least might every wind have been constant ; and no longer the capricious agent which so many are, the varying one which all are found to be. Yet thus would not the Creator's beneficent intentions have been fulfilled : while, to effect those, He acts in a manner that we should not have anticipated, and through secondary causes that we cannot explain. Leaving out of the

question all considerations of the distribution of purity, or of rain, or temperature, would commerce and navigation accept such an arrangement? I need not ask the question. The winds become variable and capricious where nothing else could have served the appointed purposes : and let all the irregularities be what they may, the vessel navigates these capricious winds, quits them to traverse the globe under the guidance of those which never vary, and returns to its home, under averages of time which we should scarcely more approve though the regulation of everything were in our own hands. If there are exceptions, if we ever fancy that we have cause for complaint, if we are sometimes steadily opposed by the regularity of West Indian breezes, it is only to say, that throughout the whole system of creation there are found defects ; necessary, permitted, or ordained.

There is one conclusion at least which will scarcely be questioned on due reflection, even by mere philosophy, independent of all piety. The Creator of the atmosphere and the Ruler of the winds did not create in thoughtlessness, and does not rule in caprice. He had purposes in view : and those He has accomplished. That they were good, we know, for we feel the benefits : and thence are we sure that the causes are under His guidance, obscure as they may be to us : for whence do we receive benefits if it is not from Him ?

I proceed to terminate, with matters of far less import and brilliancy : but be aught in Creation what it may, all is of His planning and doing, and all is good in its kind. The winds aid, by agitation, those motions of the fluids, in plants, which, in animals, are assisted by muscular action, or by what is termed exercise. The

exercise of plants is passive, but it is effectual. Of this and its effects, there ought never to have been a doubt : since thus it is that single trees are vigorous; and that the exterior trees of the forest are stronger than those within ; and this, independently of the action of light.

It is, finally, an extensive and valuable purpose attained through the weight of the atmosphere, that it thus becomes the medium of motion to a very large and important portion of the animal creation ; being a counterpoise to their specific gravities, and the resisting body to their efforts : as its great mobility, united to its universal pressure, serves to diminish that resistance which would otherwise impede their efforts and obstruct their motions. Did the atmosphere possess no other properties but these, and possess them for no other ends, it would be deemed a beautiful contrivance, as the utility would have justified its appointment. Much more therefore ought we to admire the resource which has added this to all its other duties and properties ; or, if those should be deemed the fundamental intention, has thus contrived to profit still further by them, in adapting a form of life and organization suitable to those conditions.

The final conclusions to be drawn from all this may have often occurred throughout this work ; but why should they be omitted where they are so obvious ? Had the causes which operate these effects, in the hands of the Deity, been easy of investigation, we should have known them : if the latter be deemed contingencies or necessities, what is this but to judge of His designs through our own ignorance, or, what is worse, to say that the world is governed by accidents, by chance ?

Our very ignorance, our difficulties, our disappointments, ought to lead to the right conclusion. That which we believe to be a cause, is departed from, or opposed: the effect that ought to result, does not. There is then, at least, a Cause beyond all that we see: an intèntion to produce an end, as that end is for ever produced. This is God, designing, powerful, and beneficent: and it is God, wise beyond all our conceptions, doing nothing in vain, extracting the most discordant uses out of everything which He has appointed, and effecting everything so simply, and so easily, and so regularly, that we forget the ingenuity, doubt the thought and the design, and overlook the beauty and the perfection.

CHAPTER XXXIV.

ON ELECTRICITY AND MAGNETISM.

IN the two powers, or sources of action in the universe, which form the title of this chapter, we are unable to infer design and intelligence, because we cannot trace a plan: nor can we prove wisdom in a satisfactory manner, when we do not see how it has proceeded, however wise we may perceive the results to be. The power of the Deity is therefore the obvious inference, under all these mysterious portions of Creation, where we are inquiring of actions rather than of matter and forms; while the mystery itself renders the impression deeper, though the idea of power is then less definite and accurate. My notice of these two subjects must therefore be slight. It is true, that they comprise a great range of facts, highly interesting under natural philosophy: but they are purposeless to the writer on the present subject, because they cannot be brought to bear on the reasonings of natural theology.

The nature of Electricity is one of those great mysteries of creation which are still concealed from us. It has been termed matter, and it has been viewed by others as motion. We can form no conception of matter under such a modification, and possessed of such powers: and they who speak of motion as explaining this power, or Light, or Heat, should first explain what is the substance thus moved, and what is the nature of the force producing those motions. The motion of

nothing is a nonentity : and moving power is spirit, not matter. Electricity is related to the chemical power : yet in spite of all the facts and theories yet produced, there is no proof that it is the essential agent in chemistry, as it may often also be an effect where it has been thought the cause.

That it is a great and a powerful agent of the Deity, we cannot doubt, on the general presumption of great ends where there are great means. It seems to exist, and even to abound, everywhere in nature ; to be ever in us and about us, though invisible and insensible. That it acts, even under this tranquillity, or apparent nonentity, we cannot but believe ; while it must also act widely, or universally, since it is everywhere : and we thus gladly attempt to solve, through its agency, such actions in nature as we can explain in no other manner. Yet we can prove little or nothing : often doubting, even when we have supposed it a cause, whether it may not be an effect. Nearly all indeed that we do truly see of it, are results or effects in which we discover no purpose, magnificent and terrific as they are, and indicating as they do an uncontrollable power, limited by neither space nor time ; acting without warning, arising nowhere, reaching everywhere ; contemptuous alike of vacancy and solidity, the power which flies through solid bodies as light does through empty space, unchecked, unretarded : attaining him who vainly strives to shelter himself under that which is his protection from light and heat, and from the mechanical powers : the emblem of the all-seeing eye whose penetration nothing can oppose, of the all-reaching Power which man cannot evade, though he could command the mountains to cover him.

We know a few of the mechanical effects of Electricity, and we believe that we know some of its chemical ones; but this is all. How it acts, we as little know, as what it is: of the nature of its connexion with light and heat, connected as it is with both, we are utterly ignorant: nor have we even fully convinced ourselves that the most convenient hypothesis respecting the mode of its existence is its true theory. But this forms the pursuit of physical science: when it shall have succeeded, natural theology will be able to infer that wisdom and contrivance, in the Deity, on which it can, now, only presume, from general considerations. In the meantime, it can overstep what natural philosophy must not; in pointing out the existence of that power which it cannot trace: because it is sure that it can say, 'This is of the hand of the Omnipotent. He may have reserved this knowledge to Himself, for ever, among much more: He may not have given us faculties to comprehend that which is not matter, or which is not the motion of assignable matter: and we do not know that there is not in creation something which is neither matter nor mind; while, if there be, it is certain that we never shall form any conception respecting it, because those two modes of existence comprise the sum of our ideas, and, necessarily therefore, of our language.

Thus passing what we cannot comprehend, I may at least say of the electric power, 'This is the hand of God. Is it incomprehensible? the more certainly is it of the power of the Almighty, appointed in the unseen places of creation to execute His commands. His hand directs it, as His word created it: yet, as His deputy, it possesses its rules, its laws, because His conduct is steady

and regulated, because His plans are formed by wisdom and executed without caprice. But we cannot trace those laws: we barely know something, and conjecture more. Is it not one of the great problems held forth to the active and aspiring mind of man; reserved, while it is presented under an occasional glimpse, to entice him on through those pursuits which constitute his pleasure and form his mind? And if this agent breaks loose for no apparent purposes, astonishing us by the display of overwhelming power, without adequate effects, is this mere announcement of its existence purposeless? Man might not else have known of it, nor sought to penetrate its mysteries. Here, perhaps, it is a visionary thought: but it is not a vision, that we trace, all through creation, an intention on the part of the Deity, to reveal His works to man, and, in those, to reveal Himself.

Endless books on Electricity will supply what I need state in this place. The term fluid is metaphorical, often as this is forgotten: while being carelessly viewed as if it implied a fact, it tends to vitiate all the reasonings on this agent, though it were admitted to be matter. We believe it to be everywhere, because we can cause it to act in every place, at any time: yet we do not know whether it is dormant or acting, when it is non-apparent, or whether motion is essential to the electric power; whether it only exists through motion. We see the effects of its motion, but do not know whether we see itself, in seeing the light by which that is accompanied. We suppose that it moves because its balance is disturbed, or that it is ever seeking an equilibrium: while the theory which at present we seem compelled to adopt, teaches us also, that a large quan-

tity of this power can be accumulated in a small space, and in a dormant state. And the provisions for its motion are as mysterious as all else: everything is equally perplexing. It is collected by heat, by chemical action, and by friction; and is retained by some bodies, but not by others, for no reasons that we can conjecture in their natures, as we see no purposes in those distinctions. Thus it pervades those which do not retain it, as if they were nothing; while this property also appears equally arbitrary and purposeless. Thus too do the unsuspected accumulations of this power break forth with an energy that cannot be resisted, destroying the substances which refuse to give it passage; we equally know not why. In motion, it is light, or a source of light; resisted, it is heat, or a cause of heat: and, between its desire to move and the opposition which it meets, while we cannot see why one body should oppose it more than another, or why the most dense should give it the freest passage, when the reverse ones refuse that, it exerts the most tremendous powers over the latter: the mysterious terror of the world in the thunder storm, the avenging and interposing hand of the Deity Himself, to those who seek for miraculous interpositions, in the rarer appearances of nature.

Such are its most obvious characters and effects under natural philosophy. Transmission and non-transmission, disturbance of equilibrium, equalization; motion, so rapid as to resemble that of light, communicating motion to bodies, or to their parts, and thus disrupting, or fusing them; light, heat, sound, odour, and lastly, action on the nerves of the organized bodies, stimulating the animal and vegetable muscular motions, with pain

to the former, and, in excess, with death to both. That it has any essential relations to the nervous power, is a mere speculation.

All this implies a sufficiently mysterious collection of facts, now familiar to every one. But it performs, or is concerned with, much more, under greater obscurity, if possible: and here commence those actions under which we begin to trace a purpose, the apparent end designed in the invention of this agent. The other facts may be, for the greater part at least, purposeless; contingencies implicated under those ends for which it was appointed, yet indicating its rules of action, or pointing out the order and the machinery under which it is commanded to proceed. In the present cases also, we are often at a loss to know what is cause and what effect; though willing to think that so great a power must be the cause in all cases, especially when we cannot perceive any other. Thus we find it concerned in evaporation, and in the conversion of vapour to water; while, being aware of its perpetual presence in the atmosphere, and also knowing that this is one of the substances which opposes its progress, allowing it therefore to accumulate, it is not an unreasonable conclusion that it is a chief agent in all that belongs to the management of this important body. This also may be the sole end of the electric power, because it is a great and a worthy one. But although this were proved, it is a knowledge which ends almost where it begins. The sun appears to be the impelling force of light: but the prime mover of Electricity is unknown. As yet, He who created this power holds it in His own hands: this is the abyss which we cannot pass; if indeed, as in gravitation, it be not the impassable.

The actions to which I have alluded, being changes in the forms of matter, are claimed by the science of chemistry; and here commences the connexion between the electric and the chemical powers, traced through many other actions, of the most unquestionable right under this science. But I need not pursue here, an inquiry which is scarcely more than commenced: natural theology must wait till it is further instructed by science. Yet it must be remembered that philosophy is ever seeking to simplify, because one of its dogmas is, that the Creator works by the simplest means. It may be the fact, in the present case: but though it were proved, that would not prove the broad assumption true. I have often shown, throughout this work, how the facts disagree with it: and I have never understood on what grounds, or by what right, we are to establish such a rule of conduct for the Deity, or consider it a general law of His works. This broad inference is peculiarly valueless, when it is the conclusion of mere mathematicians, arguing universally from that selected portion of creation in which simplicity was an essential principle, or where the reverse conduct would have been unwise, which, in the Deity, implies the necessity of the actual proceedings. It is an attempt to assign His whole character from a single portion of His conduct, which is unsound reasoning in metaphysics; and it is to be ignorant of creation, which shows that His power is unlimited and His resources inexhaustible. Electricity may be the ruler of chemical action: but the attempt to prove it, under the bias of this favourite dogma, tends to pervert our views of the facts, as well as our reasonings. The Deity may use but one agent, where we imagine that we see two; but we must not assume this of Him,

because our own resources are limited; above all, when He does not appear to have given us faculties to comprehend all the means by which His unbounded power governs the universe.

In the mean time, natural theology must rest in the contemplation of that mysterious power which he has reserved to Himself as one of His ministering Spirits, as far as we can yet perceive: though perhaps to communicate the mode in which He conducts it, to future races of men, as He conceals it at present for good purposes: if indeed there is aught between His will and the obedience of this great and dark power. Whatever He does thus conceal, we may be assured that the reasons are good, though we may not conjecture them: but is it not true, that man has too often forgotten Him, in learning to scan His works in their immediate causes; and is this not the very common source of the false philosophy which I have so often examined? Even the corrupted and vain philosopher can scarcely avoid acknowledging Him amid the mysterious and the inaccessible with which He has surrounded Himself, though he may not betray that conviction; while the ignorant can see Him nowhere else, since to him, it is mystery alone which is power, as obscurity is the only source of awe. The savage who forgets his God in the sunshine, falls down before him under the bursting of the thunder: and thus may the philosopher himself incline to believe that there is a Hand and a Power above him, when it acts by means which he cannot comprehend, when there is something unknown, invisible, all-pervading, ever around him in the silence of suppressed power, and ever ready to break forth in terror and destruction.

Of Magnetism, we know even less than of Electricity. Contemplated in the infancy of philosophy, it was the mystery of a living spirit inhabiting inanimate matter ; an inclination, a will, a consciousness, a sympathy. It was a far deeper mystery, when it was afterwards discovered that this sympathy extended to the ends of the earth ; when the active and living needle, untouched, uninfluenced by aught of visible power, ever restless till it had attained its own will, displayed affection, or demonstrated obedience, to an unknown, removed from it by all the interval which lies between the equator and the poles. It was scarcely to be credited : man would not believe it now, without demonstration, were it to be discovered for the first time, to-morrow. And it is a mystery still ; though we know more of its motions and affections. The difficulties indeed are accumulating, without yet showing any tendency to solve the mystery of Magnetism. Philosophy speculates, as usual ; but accounts for nothing. Like the Arabian tale, it has long sought for an iron pole in the extremities of the globe ; led astray by a worthless analogy, when the facts themselves suffice to contradict that inference.

But it is not so insulated a power as it once seemed. It had long betrayed some connections with heat : it has now displayed some with light, and with the electric power. But I need not detail facts which lead to no conclusions ; even for my purpose. Yet here too, philosophy seeks to simplify ; misled perhaps, again, by the same dogma, or possibly unwilling to grant to the Creator, powers and resources which He chooses to reserve as His secret, or to allow that He can know or do anything which itself shall not also know or explain. I must here be satisfied with stating what is of the most common knowledge ; for in this does my purpose lie.

. It is true, that Magnetism is not so narrowly limited as was once supposed, that it is not even confined to the metallic bodies ; yet there is one metal, and scarcely more than one out of this long list, to which this secret power chooses to attach itself in a conspicuous manner. We know not why the choice or the exceptions ; since we know of nothing in which iron differs from the other metals, more than they all differ among themselves. Are we to believe that if iron (and I must add nickel perhaps) had not existed, we should never have known of Magnetism, that its only real office on earth is to influence this metal, and that polarity is the purpose and the boundary of its power ? Be it so or not, where is it when it is not attached to this substance of its choice, or to any substance ? does it perform anything else ? whence does it come, and whither does it go ? Nor can we trace any connexion between local magnetism and polarity : we cannot see but that the useful end might have existed, without the other ; while assuredly the local and limited action is not that which also extends to the poles. The mystery is sufficiently great, throughout ; but it is, in one sense, the greatest, that its perhaps most striking power, in approximating two pieces of iron, should be without utility, while it does not seem a contingency on the other.

If the mystery of polarity ceases to excite wonder, from its familiarity, so is the pride of philosophy ashamed to wonder at anything : being one source of its never-ending hypotheses. There will be no cause for shame at having wondered, even when the mystery shall have been explained. The needle is actuated as by a living spirit. The power which moves it cannot be matter. It is without weight, even as light is ; but it has not

even the projectile force, or the other apparently mechanical properties of light. Electricity, light, heat, are everywhere, as gravitation is: but Magnetism, under similar mysteries, appears to be limited, and even minutely local, while its operations are more like what we dream of magic, than what we might infer of physical powers. It is the source of motion, and of a motion peculiarly limited and determined; yet almost in one body only, and to only one end. That motion is not impressed, by a remote terrestrial magnet, on the needle, through any sympathy; for this is inadmissible doctrine: it is therefore communicated by streams of magnetism, it has been said. But what are the streams of that which is not matter; or what is motion, which is the motion of nothing? Yet these streams, for ever flowing round the globe, if the fact is to be so, move nothing but the casual fragment of iron which they may meet; nor even that, unless it has received, no one knows whence, some portion of the same, or an analogous property, making it responsible to those biddings, or enabling it to receive the impulse under which it is to act. This cannot be understood. But it is mind, at least, which originates motion, be there an intermedium or not. The hand of Power directs the needle; in whatever manner: and it will ever be the moving force, discover what else we may. At present, we must rest in that, whatever more we may desire to know; and when we shall know all that we desired, the conclusion will still be the same.

I need not describe the variations in the directions and the inclinations of the needle, since they teach nothing for the present object; and, as far as we yet see, are purposeless, or, as the utility is concerned, worse. We

perceive neither contrivance nor object, neither wisdom nor beneficence : and thus does our ignorance of the physical government of God prevent us from judging of His right conduct, in this, even as it does in the moral world. Thence, as I formerly remarked, the value of knowledge in enabling us to judge justly of the rectitude and the wisdom of the Creator ; since the substitute which religion affords is not of universal influence for this purpose. But there is utility extracted from the essential property of the needle ; while it is my duty to inquire of the intentions in the appointment of this agent, of the final cause of that which cannot but have had an object.

If there are any who join La Place in ridiculing those who believe that the moon was created for the purpose of lighting the earth, he who ventures to assign the use of polarity as its end, cannot hope to escape the same judgment. On this subject however, so little fashionable among philosophers, I must still side with Hartley, against Des Cartes : as I cannot understand the temper of the great mathematician just named, far less his reasoning. And that which we believe to be truth, is best expressed with the least circumlocution : the final cause of the polarity of Magnetism is, Navigation.

Why should this not be ? It is a question that will be found more difficult to answer, than he who admits that ridicule is not argument may at first perceive : unless indeed the answer be founded on a broad denial of God's government. And he who attempts to prove the proposition, must do this from the general analogy of creation ; as being the only manner in which we can infer the Creator's intentions on subjects respecting which there is no specific revelation.

I need scarcely repeat, that the universe itself, and all the great powers by which it is moved and governed, were created and appointed for the use of animals. I know not of any philosophy which would undertake to deny this: while being the fundamental argument on all these questions of final causes, it has been, very singularly, overlooked by La Place and those who reason with him; who appear to have lost sight of the purpose of an universe, in labouring to ascertain the nature of its construction. For what other imaginable end, if not for this? It is therefore a minor and included inference, that every portion of the universe, every object and every power in creation, were intended for the same purpose: as it is bad logic to retract, whenever the individual adaptation or end is pointed out. Was light created for the use of animals? This is a vast invention, for the sake of animals so “contemptible;” for in this assumption respecting the Creator and His creatures, consists one of the chief grounds of opposition. And chemistry; and all else? There is a greater invention than all these, for the sake of animals: and that is, life.

But minor details may still be refused, though views like these may not. The machineries of swimming, and that of flying, are special inventions, for the use of inferior divisions under the great mass of animals. To breathe with lungs under the life of a fish, is an invention for the sake of a very small tribe. It is a singular invention and effort of power, to have given the means of collecting Electricity, in the midst of one of its conductors, to three fishes out of the hundreds of thousands of created species in the animal world; and for no other purposes than that of securing prey, and of defending themselves, when they could have no peculiar claims on

such an interference in their favour, and when those objects are effected, for all the rest, by means of a very few far simpler contrivances, demanding little invention. It is a remarkable act of exception under a final cause, that out of four thousand fishes, only two or three should have been provided with the means of flying. And it is reducing this minuteness of attention respecting ends, for the wants of animals, to its lowest term, to find the bee instructed in one definite rule of an abstruse geometry. It is the absolute individuality of the Divine attention to the wants of a single animal; and for no other purpose but that which seems to us, not merely an insignificant, but a contemptible end. Yet has the generous, the kind Creator of the bee, who intended nothing,—no ends in all that He has done, interfered in giving it a portion of His knowledge which He has withheld from man; that He might prevent this poor little animal from wasting its labour and its materials.

I might add further examples in abundance; but the proof is perfect without them, if there is aught of the Divine conduct which can be proved from creation. And the conclusion is, that when the Creator designed the universe, generally, for the sake of animals, so did He design individual parts of it for the use of individual animals: while the proof being drawn to a single point in the last case, the analogy is also brought to bear minutely on the very subject in question.

Of all the animated world, man has received the greatest proofs of specific attention: the machinery of his mind alone, is a sufficient evidence of a great invention for his sake exclusively. Claiming permission, for the present, to apply the term difficulty to the Deity, it

will not be said that polarity is a greater or a more difficult invention : while the argument against final causes in this case must rest on the want of will in Him to make any exertion at all, or the want of will to make a great one for what we deem an inadequate purpose. Each ground is thus answered : but if any one desires proof of a physical invention, or creation, for man's exclusive use, no influence of authority will prevent me from naming the moon. The winds would have sufficiently agitated the ocean, as they do in many seas : I may set aside this vulgar reason for the tides ; and thus safely conclude, that their sole use is their utility to man. Nor is its light of any use to the inferior animals : the nocturnal ones are so contrived, and necessarily, as to dispense with it. I can therefore see no defect of reasoning, in philosophy, or in logic, in concluding that polarity, and probably magnetism, is an invention for man's use, when the great globe of the moon was created for his exclusive advantage.

And the end was a great one : navigation, the mutual communication of the great society of mankind : while the means are as perfect as the end was great, and not less simple than perfect. To have found, that with so valuable a purpose, there is no other, would be an argument, in any case but this : where the objections ever originate in a false hypothesis respecting the nature of the Deity, and of the relations between ourselves and Him : most commonly, but not always, in that most unreasonable one, which presumes that He takes no interest in His creation ; sometimes from the more pardonable fault which ascribes to Him a false kind of human dignity, incompatible with the Parent of the universe, to whom alone it belongs to reconcile the most

minute beneficence and care, with an elevation transcending all conception. And polarity is the simple invention which I have termed it; mysterious and incomprehensible as the means may be. No thought could suggest one more simple or more efficacious. A fragment of iron, existing everywhere, obtained without cost or labour, becomes, in one minute, the steady and unerring guide of man across the trackless globe. Had it been of human invention and monopoly, the wealth of nations would have been worthily expended on the purchase of what the Creator has bestowed on us out of the freedom of His inexhaustible beneficence. And it must not be said, as La Place has done of the moon, that the imperfections which beset this use render the present deduction null, or that the recent discovery of that use is an answer to it. The former is true of everything in creation; and the latter is in the proceedings of God's government for man, in all things.

But it is by feelings, as usual, and not by reasoning, that this matter will be judged. By those it will be determined, whether the needle, the bond of nations, as the ocean is their highway, the guide which conducts man over the earth, that he may fill its vacant places, the invention which multiplies the productions of the world and the numbers of men, which equalizes its climates in diffusing their produce, whether that instrument which is commerce, rendering all mankind one wide family, be an invention of the Creator for man's use, and a special instance of His goodness to the human race, as it is among the peculiar efforts of His power.

CHAPTER XXXV.

ON HEAT.

IF a fundamental defect in our divisions of science has been the cause of much imperfection and confusion, it would have been well if nothing worse had followed ; since we can safely trace a vast mass of hypothesis to this defective division. In the early days of philosophy, mechanics constituted the only science ; and its principles were therefore necessarily adopted to explain everything. What the success has been, I need not here say : as I have more than once had occasion to trace the errors and the dreams of philosophy to this source. It was late when chemistry took the form of a science, and still later before it knew with what powers and matters in nature it was, or might be, concerned. Whatever it did effect, mechanics, at least, retracted some of its claims over that in which it was powerless, yet not so readily or fully as it ought : while the new science, still ignorant of its own nature and rights, and infected with the habits of the old one, aided it in the attempts to reduce to mechanical principles what it did not choose to abandon, by adopting from it those corpuscularian hypotheses on which I have sufficiently remarked elsewhere.

In the mean time, the phenomena of light had begun to demand attention : and thus, in the infancy, or almost

before the birth of chemical science, the mathematicians attracted it into the vortex of their own. With what success and effects, I have noticed in the chapter on that subject: while chemistry has in vain attempted to vindicate its share in light, notwithstanding its attempts, and the connexions which it possesses with that power. But light had long remained in the possession of mechanical science, before it knew, or even suspected, enough of the nature of Heat to put in the same claims as it would probably otherwise have done. In the mean time, chemistry had been growing up: when, at last, its cultivators being the first to observe, and to explain, as they best could, some of its laws, it became their property, while there was at least no fitter claimant at that time. It did not however perceive, as soon as it ought, that it had undertaken a subject beyond its powers; and was obliged to leave in obscurity more than what it believed itself to have illustrated. Of this the mechanical philosophers were sufficiently ready to remind it: and thus did that philosophy attempt to bring the investigation of heat as well as light within its own circle.

Hitherto the success has not been great: it may be asked whether much of this failure has not arisen from this twofold division, and these too narrowed views, of science. If chemistry can establish no juster claims over the radiation of heat than the propagation of light, so is there much more where its rights are as questionable, unless its definition be materially extended. And if the rights of mechanical science over the same powers and actions are to be judged of by its success, they alone who are easily satisfied will admit its claims. But it concerns philosophy, and not my subject, to con-

sider whether in these and the other mysterious powers and actions of nature, there is not something which demands a separate science. What form this may hereafter take, or what it may effect, no one can foresee: but in ridding itself of the chains, alike weighty and useless, which now bind its choice down between a dilemma, it will at least be free to invent new hypotheses, should it not indeed succeed in effecting somewhat more.

For the present purposes, under those reasons and others, I have separated the consideration of heat from that of chemistry; though the entire separation is at present impossible, from the great share which this power takes in chemical action. And, as in all else here examined, it is the facts and their results which chiefly concern natural theology. It would have been useless, at any rate, to argue the obscure question whether heat is a substance or a power: but what I have said respecting light applies equally to both these mysterious entities. There seems indeed even more of mystery in heat than in light; in as far at least as it appears more thoroughly independent of mechanical laws. If the deflection and the refraction of light have really that dependence on this science which has been presumed, there is nothing in the proceedings of heat which seems amenable to its rules: and if, assuming that each of these entities is matter, the perpetual disappearance of the immense floods of light ever issuing from the sun is a sufficient mystery, that is exceeded by the dormancy and the revival of heat, in the several changes of condition between the solid and the gaseous states of bodies.

It is needful however to point out some more of the difficulties belonging to the theories of heat: not that

I may expose the presumption of philosophy, but show its insufficiency. It is out of the dark depths of our own ignorance that we best lift our eyes to the splendour of the knowledge of God: and if they who mistake words for reasoning, and phraseology for science, must be checked, so must pure ignorance be told how much there is in nature which it never imagined, that it may the better know what He does, and feel what He is.

Dormant heat is a substance at rest, and in union with matter: sensible heat is that substance in motion. This is easily said; but we must ask, what substance? how combined and rendered immoveable? how moved, and by what power? how moving in a mass of heated iron? how converted suddenly from the extreme of motion to absolute rest, when a body changes its condition? The doctrine of undulations, or vibrating motions, has also been applied to heat, as to light: and since there can be no motion of nothing, there is an ether ready for this use also: whether another, or the same, is of little moment to those who desire ideas. This, it is easy to see, is an offspring of the mechanical philosophy, like the hypothesis of Hartley on a far other subject: that nightmare of science which has so long and so widely oppressed it, chaining down those who cannot or will not open their eyes to the light; or the ever ready expedient of that ambition, so prevalent in philosophy, which is as well satisfied in being thought to know as in knowing, in being venerated as a teacher, as in truly teaching and teaching truth. It is the same shapeless form that haunts us when it instructs us how bodies are expanded by heat. The ultimate atoms receive atmospheres of heat, as the repulsive power, and

the repulsion is proportioned to the magnitude of the atmosphere. Is there any one who can seriously receive so vulgar an illustration as a fact? Who knows aught of atoms or of atmospheres? The very basis of a theory is wanting. But though this were the theory, the mode of the induction, retention, disengagement, the proceedings in the diffusion or the escape, or in the latency, are not explained: while no ramifications from this or any other hypothesis, account for radiation under all its singular variations, any more than for those which occur in the diffusion of heat through different bodies. We have instructors indeed in all these things: but is there one who both understands and believes what he teaches? If mathematicians are here influenced by their exclusive science and habits, so do they commit the error of converting a metaphysical assumption into a physical fact; as in other cases which I have elsewhere pointed out. It is right that they reduce to the language of mathematics that to which they can apply mathematical calculation. The ingenuity which they have thus displayed is admirable: the sagacity and patience by which they have extracted truth from their hypotheses and fictions, almost exceeds our belief of human powers; and thus have they performed wonders in natural philosophy. But it must not be forgotten, that while the truths thus sought have been found, the symbol is not a fact, and the fundamental hypothesis not one of those truths.

I need not proceed with this, since natural theology can extract from it no further uses than those already suggested: that of acknowledging the First Cause where we can see no other, and that of contemplating it in all the unintelligible of its wisdom and power.

But such a notice was also needful ; lest the language which I must hereafter borrow should be considered as representing known facts and definite ideas, when it is but that of necessity or convenience.

If I have elsewhere termed Chemistry the life of the material universe, I might apply the same term to Heat. In a philosophical sense, it is such, even as chemistry is ; being, in reality, an essential portion, or the one half, of chemical power, if that consists, as is thought, in the attractive power of matter, and the repulsive power of heat. In a popular sense, the propriety of this term is more obvious ; since not only do animal and vegetable actions cease in its absence, or at some stage of its diminution, but even the insensible substances around us appear to become dormant and dead. We know not whether there ever is, or can be, such a condition as absolute cold, notwithstanding the experiments and inferences which chemistry has produced : but we can believe this to be the universal death of nature, though unable to conceive what matter would then be : since we must consider attraction as a perpetual tendency to rest, and its perfection as absolute rest, or death, while heat is the counteracting and the moving power.

The great and conspicuous source of heat to us, is the sun ; and it is, doubtless, equally the produce of every star. But science is not yet agreed respecting the mode in which it exists in the sun, or is propagated to us from that body. It is radiated, like light, and with light : it is a mode of light : it is excited in the earth by the action of light : it does not exist in the sun ; or it is there, dormant : of such, and more, have been the speculations of philosophers, variously supporting these by facts, of some kind. But of those hypotheses I need not

here inquire. Existing in space, as modern observation shows, it is the produce of radiation, and, as we may infer, from all the solar bodies of the universe. It is not doubted that comets are sources of heat as well as of light. That it exists in the moon and the earth, independently of the sun, we know from their volcanoes: and thence we may infer the same of every other planetary body: while if it be true, as elsewhere suggested, that the interior of the earth is a fluid of fusion, the same should be true universally, and every planetary sphere an independent focus of heat.

Such heat must be considered as original: or to be, in our earth, where we are most sure of its existence, independent of those chemical actions among its constituent parts which are also productive of heat. Those I must next consider: premising as much of the general facts and the usual explanations as is necessary for understanding this part of the subject. For details under each, I must refer to the well-known books on chemistry.

There are three conditions of bodies; the solid, the fluid, and the gaseous: and it is concluded that all substances are capable of the whole, though it has not been proved of all. If a solid body becomes fluid by continued additions of heat, some portion of that remains unaccounted for, or disappears: it becomes insensible; dormant, or "latent:" and the same happens when a fluid becomes gaseous. Reversely, when a gas becomes a fluid, or such fluid a solid, heat is perceived, or produced: that which was dormant becomes sensible. The general conclusion is, that the second and third conditions are dependent on two different proportions of heat, combined in some manner with the original solid. The

practical result, which is the one that concerns my purpose, is, that the two changes downwards to the solid are sources of sensible heat, as the reverse ones produce sensible cold. This is the simplest view; making the combination with heat the cause of the changes upwards: I need not here state these facts under another well-known phraseology, nor discuss the relative merits of the two.

Further, when two different substances, be they compound or simple, under chemistry, unite to form a new one, there is often a change of temperature, and sometimes a very remarkable one: the new substance is hotter or colder; and, in the first case, this also is a source of sensible heat. It explains nothing more, to say that the new body has a greater or less capacity for heat than the original ones: science indeed terms this a theory; but, as in most of its other theories, the minutest portion of logic suffices to see in it nothing but the substitution of one phraseology for another.

This is all that chemistry offers in explanation of those sources of heat which are not in the solar bodies, nor inherent in the planetary, and also the cometary ones: while I do not here notice Electricity among these, since that is treated of separately, and since the cause of the heat attending its action is very obscure. Unfortunately, it is very unsatisfactory, though it has long passed with little or no inquiry: since it will not explain so common a fact as the heat produced by the combustion of gunpowder: and with this, I may safely say, that produced by the combustion of many other inflammables, possibly all: though there is no case so pointed as this one. Practically, however, as being that which here concerns us, this is fire, the great source of

heat to us, after the sun. The burnt body is converted into some other, or more than one, by heat, or is decomposed and recomposed; producing light together with heat: though, here, the connexion between the light and the heat is as obscure as in the case of the sun, while that between the former and the burnt body is utterly unintelligible: since the received theory will not apply in the case of nitre and in some others, and is therefore, as a theory of any case, worthless.

It remains, under the connexions of chemistry with this subject, to state the production of heat by animal bodies, and apparently, if in a far inferior degree, by plants: but though referred to chemical actions, the real nature of this source of heat remains obscure; as it would seem that the nervous system exerts some action not explicable on chemical principles.

The mechanical sources of heat are condensation and friction. The former is explained, in a manner much more easy than satisfactory, under the terms approximation of atoms, investing atmospheres of heat, and capacities for heat; since the first are themselves hypotheses, and the latter is little more than a substitution of terms. Friction, including collision, either remains unexplained, or is supposed to imply condensation: which, were it even the fact which it, often at least, is not, is explaining through that which remains itself unexplained. And with whichever of these, as causes of heat, the extension of metals must be ranked, the obscurity, in this case, is equally great at present.

I must now describe, with equal brevity, the modes of communication appointed to heat, as a sensible entity. These are, the conducting power of bodies, causing its transmission through matter in continuity or contact,

and their radiating power, or that through which they project it to a distance, through space, in the same manner as the sun transmits it to the earth.

Under the former law of heat, if two parts of one body, or two bodies in contact, are of unequal temperatures, the inequality is gradually reduced. It is a perpetual tendency to an equilibrium of heat: and this equilibrium is produced with more or less rapidity, in proportion to certain obscure properties in different bodies: while there are cases in which the retardation is such, that the process of diffusion seems at length to stop entirely: though that which is a practical nonentity may still be a mathematical quantity.

The perfection of the radiating power seems to exist in the sun, with which doubtless we may include the stars: and it is presumed, but not proved, that the velocity of heat is, in this case, the same as that of light. This assumes absolute linear motion in light and heat both. As far as the theory of undulations can explain anything, it may equally serve for both. The same power exists in fire, or in the heat of combustion, whence one of its valuable uses; but the energy or velocity, either in this case or any other, cannot be compared with those of the radiation of the sun, because even the laws of this are unknown. Lastly, and, generally, every body possessing heat, from whatever cause, or being of a higher temperature than some other body, communicates heat to it by radiation, be the distance what it may; so that, like the conducting power, though under very different circumstances, it is a mode of producing the equilibrium of heat. And as the conducting property, in different bodies, varies exceedingly, so does the power of radiation: yet in the latter case, under a more

mysterious aspect; since it is dependent on surfaces, and even on colours, as well as, apparently, on composition or nature.

If I have just shown the inefficiency of philosophy to explain the sources and nature of heat, I may repeat the same remark respecting its motions. The motion by transmission seems indeed so very natural, or necessary, that little comparative anxiety has been shown respecting it. Yet we can, in reality, form no definite ideas with regard to the cause or mode: while the inequality of the conducting power in different substances, ought to convince us that our difficulties are as great in this case as in the other. The cases of glass and of stony substances prove that this power is not dependent on density, should we have judged so from those of cork and wood: while the inequality of power where the densities are little different, as in some of the metals, confirms this still more. If the motion through radiation is to be solved by the mechanical philosophy, as that of light has been, I need scarcely ask what conceptions can be formed of mechanical impulses produced by the bodies which radiate, above all, by surface, polish, or superficial texture, or colour, whether we suppose the actual motion to be linear or undulatory. This case is even more difficult than that of light; since the radiation from a given body is checked by an equivalent heat in another distant one; a fact, of which no mechanical theory can give the least possible explanation: but we see the utility of the law, since the purpose of radiation was equilibrium.

But enough of the philosophy of heat, such as it is. And now, who is there that must not admire the Hand which has produced such a power; so active, so uni-

versally pervading, so mysterious, and effecting such wonders : which has so appointed and regulated its production and communication, and so ordained it, that there is nothing in which we do not see utility and beneficence combined with wisdom and power. Its mysteries are inscrutable : and what we can neither explain nor comprehend, is Power beyond our conceptions. The splendour of the Divine power is seen in its effects ; so that the loftiest of poetry has surrounded its God with fire, as with light. Its universality is felt in the extended sway of this great agent : and we know not how sufficiently to admire the power which reins in this free and wild and active and omnipresent entity by laws so simple and so few. Still more is the Hand beyond our comprehension which produced what cannot be matter, and is not mind ; and what cannot be motion alone, because, without matter, motion cannot exist : which fills the universe with this active existence, this motion and source of motion, ever producing the greatest effects, yet ever unseen, and untangible ; imponderable, yet unrestrainable in its influences over matter. It is a marvellous Hand which, by the addition of that which is imponderable and insensible, enlarges the dimensions of bodies without limit : and there is no Hand but that, which could have taught this spirit to withdraw itself again, restoring these to their former conditions. No power but that which produced light, could have enabled this invisible existence to traverse the universe with, perhaps, the velocity of light, and could have empowered it, still further, to find its way through solids impermeable to this rapid agent. Is it not a more wonderful and mysterious agent than even light itself ? Like electricity, it sleeps and is forgotten : its activity is quenched in an instant : it appears to be nowhere ; an-

nihilated : yet it is still everywhere, and ever ready to revive in fresh power ; renewing its activity in an instant, at the command of Him who ordained it, and appointed the rules of its obedience.

To our experience it is the opponent of attraction, though science may not explain the nature and the causes of these actions ; of that equally mysterious power through which it is, that there are solids, fluids, gases, that the solid is not a fluid, and the fluid not a gas, that the gas does not diffuse itself to be lost in space. In each case, the mystery is equal, the power incomprehensible. An unknown entity, a spirit and agent of motion, causes matter to condense itself, or, in the language of the corpuscularian philosophy, compels its atoms to approximate. An equally unknown and mysterious spirit of motion, as if at eternal war with the other, causes matter to expand, or, in the same language, makes its atoms repel each other. And what must be the extent and accuracy of that power which has caused these two unassignable, unintelligible, spirits, uncontrollable as each, separately, appears to us who can conceive nothing bound except by mechanical force, thus to conform and obey ; thus perpetually to balance each other, under endless circumstances of opposition and contest, so that the result shall ever be that which was intended ? Yet this is ; be the manner what it may : and this is the power of the Creator. Surely too the principle must be simple ; little as we can understand it, and whatever complication there may be in the details. This is the beauty of wisdom, though we cannot dissect the constituent parts, compare them, and estimate the whole : for, to combine facility, certainty, variety, and efficacy of action, without complexity of causes, is wisdom of the highest.

In detailing the few facts which I have selected, I need not be solicitous about the order of what must frequently be divorced from their philosophical connexions, for the better attainment of the objects here desired.

The atmosphere exists but through the power of heat. That great repository of food and life, for vegetables and animals, is sustained by the energy of the mysterious spirit which formed it what it is. Thus is it the breath of the animal world, more indispensable than food; as it is both food, and the conductor of food, to plants, with somewhat more, which we cannot yet define. But as all this, and more, has recently passed under review, it will here suffice to remind the reader, that but for the presence and energy of heat, this great and indispensable portion of the globe would be a solid body, perhaps an equally unknown and useless form of matter. If it is through insensible heat that there is an atmosphere, so is it by this power, both in its sensible and in its dormant form, that the great motions and actions of the air are governed: unless as far as electricity takes that share which we rather conjecture than have ascertained. It is through heat that the water of the earth is dissolved in the atmosphere, as a store for future rains: acquiring that levity under which it can be transported with the velocity of wind around the globe. Here, it is the opposing power to gravitation, as it is, in other cases, to the self-attraction of matter. Had the problem been put to man in a state of ignorance, were it even now said to him who did not chance to know or recollect it, that water, and not only water, but the heaviest metals, could be raised from the earth, despising or renouncing that force of gravity which seems inseparable from their very existence, that neither

bulk nor weight was an obstacle to their ascent, that the whole ocean might quit the earth and float in empty space, he would not believe in the possibility. Less still would he be inclined to believe it, were he told that this was the work of a silent and invisible agent, an unseen existence ever about him, a gigantic spirit occupying all surrounding space, dwelling in everything, dwelling in himself, unheard, unfelt, unseen. Yet it is even thus: the very language in which it is here expressed is not that of poetry, but truth. The fact occurs daily; it is ever occurring. Would he too to whom this was the first time stated, believe that this invisible spirit possessed that magical power which romance attributes to its enchanters, rendering invisible, like itself, whatever it touched, and thus transporting it through the regions of air? that like the Arab Genii, it could fly with the palaces of the world in its hand across the mountains of Caucasus, hidden from all eyes. He would deny the possibility of that which is before him, daily, and hourly.

Almighty power has solved this problem; and in these very terms has He solved it: solved it too with so much ease, and so simply, that we fail to note, and forget to admire. The great spirit of Heat is the magician; but it is the enchanter in His own hands: His deputed agent, to war for ever with solidity and weight, and, in the strength of its mysterious power, to maintain life and motion within the earth.

If such is the action of insensible heat in the atmosphere, its familiar and sensible one is the source of effects which concern us at every instant, and often implicate our very existence. Whatever other causes may aid, it is to heat chiefly that we owe the circulation of

the atmosphere, with its internal motions, so important in their effects : little as we note the facts and think of the consequences. There is not one who reflects that, to himself, the repose of the atmosphere would be death, though all its chemical and vital properties remained unchanged. The motions of the air are produced by inequalities of heat, very widely, and they are an important portion of what this agent has in charge. Man would perish under the equator, he would perish under the pole, had it not been commanded to heat to expand the atmosphere, through that power of repulsion which is so simple, so universal in its effects, and so varied in its results. This useful agent itself would be his death, in the lands of the sun, did it not thus know how to counteract the evils it was for ever producing : its absence would be his death in the regions of ice, did it not make for itself a chariot of the atmosphere, that it might be transported where its presence was required. And, but for this wonderful agent, that air which his breath had converted into poison would not quit him, or he would starve in the midst of a plenty which he could not attain, and the first hour of his life would be also the last.

If man, if the whole living creation, owes this, and far more than this, to heat, as the maker and the ruler of the atmosphere, so is it equally the creator and the ruling spirit of the waters : moving the machinery of this vast element, as it produced the substance and maintains the form. Its presence is fluidity and life ; its absence is rest and death. The great storehouse of food for plants would be purposeless to their existence, did not the spirit of heat preserve it in life and motion : it would fail for animals, fail for the uses of man, had

not the Creator provided heat to rule it, and placed it under the command of that power. For this end too, as for others, He has committed this great agent to the hands of man : empowered him to seize and to wield it ; to bind, to loosen, to move, and to dissipate, the fluid element. That chemistry through which heat is produced, the mysterious powers through which it moves, have been given him by his Creator to use ; not even requiring of him to learn or know, but teaching him as He has taught the spider to weave and the bee to build.

If the machinery of the waters is commanded by the mechanical power of gravity, so also is it by heat. Through this, as in the atmosphere, are its internal motions ruled : and if the winds carry to the poles the heat of the equatorial lands, so do the currents of the ocean, under the same power, maintain an equilibrium throughout the earth, which could not otherwise have been ; becoming among the great compensators of temperature, and, like the breezes of the air, balancing the inequalities of far distant lands. The same effects occur in the atmosphere, and from the same causes ; as was formerly noticed : while if, in both these elements, this facility of transference seems to stand in the nature of a compensation for their nonconducting power, it is plain that the end, of equalization of heat, could not have been attained in this manner with sufficient rapidity. But we do not see why these elements should be similarly deficient in conducting power. In the atmosphere, the utility is apparent, in relation to its warm-blooded inhabitants : I am not aware that any use has been assigned for the nonconducting power of water, or of fluids in general.

To whatever other purposes the Creator may have applied that absorption of heat through which solids acquire the fluid state, its utility in the case of water has often been pointed out. But for this, sudden and considerable changes of temperature would render the thaws of spring sources of inundation. It is under the same general law, but in the other stage of these changes of form, that the cold produced by evaporation has been turned to those useful purposes in animal bodies which I have already explained. But neither in the case of air or water, can I pursue this subject in its details of application and use; while the preceding chapters on those elements have anticipated much that might have otherwise found a place here. And if I have noticed the different modes in which heat is produced, it is in the applications that our chief interest lies, under the present views; since it is in these that we trace wisdom and beneficence.

It would be childish to follow the writers who diffuse themselves in familiar truisms, by enlarging on the advantages which the living races derive from the universal diffusion of the sun's heat. Doubtless, without this, the world would be a desert; it is the life of plants and animals: and much more. But this is the condition under which they are created: the goodness of the Creator must be contemplated in the prime act, and the details teach no more, when they are necessary attached conditions. It is far more interesting to examine those contrivances by which, while the wisdom is evinced, the goodness is rendered far more striking; since we thus see how sedulously it has been exerted. The broad views which deal in obvious common-places are also worse than trifling: since they permit the doubts or

cavils of others to intrude the doctrine of general laws, and to infer that carelessness in the Deity which has so often been urged by the atheistical philosophy. To produce cases of specific and minute attention for the same purpose, is to defeat this equally false and ungrateful reasoning.

From the form of the earth and the nature of radiation, we see that all its parts could not have received an equal portion of heat from the sun : it was impossible, as involving contradictions. But we cannot equally conclude on the impossibility of producing an equal heat, in some manner : and as little can we say that water might not have been created so as to have remained fluid under a lower temperature than the present, or that plants and animals might not have been formed to exist and enjoy under far greater degrees of cold than they do now. We must therefore view all that now is, not as unavoidable, but as a fundamental part of the plan of the Creator, under reasons which He has not yet allowed us to know. Thus, conceding this basis, we can, usefully as safely, examine what He has done to correct the defects which He appointed, in compensating the inequalities of the sun's heat over different parts of the earth's surface.

The mechanical compensation produced by the peculiar relation of the terrestrial axes to the plane of the earth's orbit, is familiarly known, as are its effects, to those of the lowest instruction ; though they may not be equally aware of the additional one dependent on that atmospheric action which so powerfully aids the long residence of the sun above a circumpolar horizon. This compensation, from refraction, is also beautifully regulated : since it graduates in power, and vanishes when

it is no longer wanted. Like the twilight, it is a twilight of heat, if I may use such an expression: while peculiarly augmented in the colder climates, under some unknown constitution of the atmosphere which here enlarges the horizontal refraction.

I have just noticed how this defect in the arrangement of the earth is compensated by the atmospheric and oceanic currents flowing towards the polar portions: among the latter of which, that remarkable one termed the Gulf stream is now beginning to be well known. But the details are beyond my bounds: and I shall immediately point out how vegetables and animals have been peculiarly gifted to dispense with that heat which could not have been permitted under the established arrangements.

We do not know why it is that the sun's rays produce no heat, if indeed this be accurately the fact, in their passage through vacuity. But we can see perhaps a moral reason, though not the physical one. Heat was useless where its power was not to be exerted for a purpose; though we must not apply the term waste to Him who needs no economy. It appears, therefore, or is called into action, or is generated, if any one prefers this hypothesis, on the arrival of the solar rays at the atmosphere, increasing in intensity till it reaches the earth. The utility is here obvious, since the earth was the object in view: but there is also an attendant defect, while, even from this, advantages are extracted under a peculiar compensation. The elevated portions receive less heat than the lower, in an ascertained gradation: so that those which pass that ellipsoid in the atmosphere where water is always solid, become untenable by life. But thus, as I formerly showed (c. 6), a

temperate climate, or many climates, are produced in that which would otherwise be a torrid zone : while it is possible that this peculiar law of heat may have been partly, if not entirely, designed for this very end. And thus also, as equally indicated in a former chapter, the most heated portions of the land are tempered by the vicinity of the colder ones, under that circulation which results from difference of heat.

If now we turn our views to that part of creation for which heat seems, chiefly, if not solely, to have been appointed, we find an extensive system of compensation, admirably varied, and adapted to the inequalities of temperature consequent on the planetary mechanism. And, under the present purposes, it is the more worthy of notice ; because, not being derived from mechanics or chemistry, it cannot be explained through the doctrine of general laws and necessary consequences, by those who desire to set aside the Creator's wisdom and beneficence. It is a power of adaptation or conformity granted to those very objects for which heat was ordained ; yet ordained under laws directed to other useful or needful ends, and which would thus have inflicted evils on them, and opposed the general intention as to their welfare. And the power of compensation thus granted to themselves is varied according to the exigencies, while rendered perfect for its ends under every variation of heat.

No philosophy, under whatever knowledge of inanimate nature, could have devised the means of solving this problem in any manner, far less in so perfect a one. He, who is never at a loss, whose contrivances are ever beautiful and perfect, has solved it through that power which He has kept in His own hands ; through the

power of life. An instinct of feeling, producing choice, and conferring enjoyment, is given to the organized races, and, to all, under distinct desires, everywhere suited to the exact circumstances of heat in which He has placed them. He has not only appointed them constitutions suited to each temperature, but where He has directed them to live, there has He fixed their prosperity and their preferences. If there is aught of adaptation and correction in the universe more perfect than this, I know not where to seek it.

From the equator to the pole, from the torrid plain or the steaming valley to the mountain limits of life, there is a plant for every place, and to that place are its affections, like itself, rooted. Is it a climate of perpetual heat? its tenant is ever active, ever enjoying: Does the sun withdraw itself for a season? it sleeps without suffering, and is again awakened by the returning rays of the great source of heat: Is the allotted time of the sun narrowed? its activity is proportioned, and it performs, within a few short weeks, that which has occupied months to its fellows in a warmer region.

If animals are similarly concerned in this species of adaptation, the case is more intricate: while one of the modes of compensation adopted in them leads me naturally to note the little that is here necessary, on the subject of animal heat. That which belongs to their clothing will be found in a separate place, or in the present chapter, under its appropriate heads.

It may be asked, as usual, why the necessity of a heat greater than that of the surrounding medium should have been established for any animals, when it has not been so for all: this was to create a want for the mere purpose of remedying it by an invention. Physiology

indeed has not wanted its answers, according to custom, when it speaks of red blood, of nervous power and sensibility, and of the hatching of eggs: forgetting that there are cold animals with red blood, that there is great muscular power with white blood in a cold animal, that sensibility varies, all through Creation, without any regard to temperature or the colour of the blood, and that the eggs of fishes and insects are hatched at the temperature of the surrounding medium. The honest answer, in philosophy, is a confession of ignorance: but, for the present purpose, it is this:—Such was the Creator's plan; it may be purely arbitrary; but it may possess some peculiar utility which we have not yet discovered.

In the mean time we can advantageously examine the circumstances of wisdom or power under which that plan has been executed: and it being therefore assumed that a power of producing heat was necessary to certain animals, the first inquiry is, how that is effected. Here, the wisdom, or the philosophical knowledge, cannot fail to be profound, because we have not yet discovered the mode: there are hypotheses, but that is all. The discoveries already made respecting heat are proofs of our own wisdom: that there should remain what we cannot understand, is a proof of that superiority in the Creator, which we believe to be absolute. His power established the laws, or actions, of heat, for this end among others: and, following those laws, He produces the effect in question, with many more. Here therefore, unable to explain the mode, my business would have been to examine the details, had I not found it more useful to place them in the 23rd chapter; to which I may here refer.

Having rejected the usual common-places of this subject, and unwilling to pursue even the useful details to their exhaustion, I may turn to some other consequences attendant on the production of heat, which evince beneficence or wisdom.

The earth is heated by the action of the sun's rays, and the water is not. Seeing the fact, we are ready, as in many other cases, to explain why it is so, ever forgetting to ask why He so caused it. Water is transparent, and therefore transmits heat without arresting it: it evaporates, and this is a cooling process: it circulates, and thus maintains a mean or a low temperature. Such reasoning, however, belongs to an atheistical philosophy, or to one at least which forgets the Deity: seldom as this is considered, and assuredly as it would be renounced by many who now adopt it, did they recollect its origin and perceive its consequences. It belongs to a system of necessity, or even of chance: renouncing a design, or a final cause: that light, without which even natural philosophy is ever straying from the right path, and without which, man, as a moral being, strays more perniciously. Science may have assigned the reasons, or the deficient causes, truly, in the case of water, though it has not succeeded in showing how the earth is thus heated: but it dares not say that these laws, or results, were necessary, or that the Creator might not have heated the water also, by the sun's rays. We must seek for the reasons in the utility: while if that is obvious, generally, the details exceed the space which a limited work can allow.

Whatever effect the heat of the earth itself may have had on its superficial portions and fluid appendages during the remote periods of its existence, it is not

proved that this exerts any steady influence at present. But the occasional results are still enormous, as they are immense in utility, and therefore in the display of beneficence. These consequences however, whether for present good ends, or future, and even greater ones, are noticed in other parts of this work, so that the bare hint suffices in this place. That I allude to volcanoes and their results I need scarcely say; as I may refer to the 20th chapter.

The production of occasional heat, through the mutual actions of bodies, whether these be chemical or mechanical, is a general fact, involving details of an endless multiplicity and a high interest. And, generally useful to man as they are, while rarely so to any other animal, they refer most readily to the beneficence of the Deity. Without fire, the earth, over a vast extent, would have been uninhabitable by him: and the command over its applications constitutes one of the great differences between his races in the savage and in the civilized state. If I need not point out these details, and still less notice what belongs to the refinements of chemistry, the intention for the uses of man is rendered most striking by one or two simple facts; while that ought not to be doubted, when it is a great engine for the replenishment of the globe by his generations.

Who can doubt the specific intention that reflects on the existence of coal, attainable and applicable by him alone; knowing also that to produce these buried stores of dormant heat and light, required no less than a succession of periods in the incalculable age of the earth, extending to hundreds of thousands of years? Who can doubt this, seeing that while the materials

have been thus and otherwise provided, so have the means of producing fire been given to him alone? May we not even say that they have been revealed, when we find this knowledge universal? It would have been a revelation, though not given in words, to have rendered those means so obvious that man could not have overlooked them, in any condition of barbarism: and this has been done. I already remarked that science could not explain the production of heat by friction: it is a solitary law, and to us, at present, an arbitrary one; or simply, a command of the Deity. It has been ordered that friction shall produce heat, and to such a degree as to burn combustible bodies; while the specific cases that here concern us are remarkable, being the combustion of wood, and of iron. Each of these seem ever to have been known to man: that of wood occurs in the course of nature, in the forests of hot climates at least; and neither of them serves any other purpose. I know no stronger argument for a final cause, than that the cause of a given effect is peculiar, and that only one, peculiar, purpose is served by that effect.

Nor do I see that there is aught unreasonable, or fanatical, in pointing out, that, excepting the use of friction in steadying bodies, nearly all its other effects are evil, and that man has been provided with remedies against those injurious results: the whole marking the thought and care bestowed on this subject. The friction and heating of that machinery which is indispensable to man's civilized and extensive existence, by multiplying labour without multiplying men, is the evil of the same law which gives him the command of fire. The provided remedy is the interposition of oil or water. Why do not the compression and collision of oil pro-

duce heat, as those of wood do? A second arbitrary law produces a good end, by correcting an evil contingent on a prior one; and it produces no other end. I leave the conclusion to the reader. But if a blind or pernicious philosophy does not permit the Deity to pursue the good of which He laid the foundation, or, granting generally, denies the specific application of His goodness which is produced, thinking it perhaps beneath His dignity to take charge of the working of a human engine, it may reflect whether the multiplication and welfare of man might not have been an object with the Creator of man: creating him, not, assuredly, that he should be miserable, not that he should be narrowed on the earth, not that he should be inferior in power to the animals while surpassing them in intellect and ultimate capabilities, a wanderer among the wildernesses of a rude world, refusing him an existence.

Before proceeding to the few facts which I can here afford relating to the diffusion of heat, some general remarks are necessary. It is incessant: under the conducting power, it tends to propagate itself through all bodies in the earth, while, under the law of radiation, it tends to quit this globe and diffuse itself in space: as this is presumed to be the process through which the once fluid earth attained its present nature. The latter proceeding applies equally to the two great elements of water and air: but the deficiency of conducting power in these is compensated by their mobility under the inequalities of specific gravity produced by heat, as I have already noticed. And the tendency of each of these processes, I need scarcely repeat, is to an equilibrium of temperature: but the practical equilibria differ most materially in their consequences, if the dis-

tinctions are too often forgotten by those who have treated of this subject.

Within the bounds of the earth, the final result of the action of the conducting power would be a mean temperature, which, it is true, we have no means of estimating, but which, there is reason to believe, would be destructive of the order of creation, could it occur, and remain. Against this, there are two remedies; the one consisting in the production of heat, from its various sources, and the other in the various degrees of the conducting power assigned to different bodies. The former generates those incessantly changing inequalities which are indispensable to many needful actions; while the latter, in the act of tending to a pernicious equilibrium, sometimes aids in producing similar ones, and at others in checking the former: the whole displaying a beautiful mechanism, if this metaphor may be adopted, under such a combination of simplicity in the principle and intricacy in the details, that we contemplate the whole contrivance with an astonishment perpetually augmenting as we become more attentive to the facts. Unfortunately, the ingenuity and the nicety of the proceedings require much attention to be perceived, and therefore are they little noticed. It is a narrow view indeed of the utility and operations of the conducting power, to limit it to the mere communication through which bodies are warmed or cooled.

The tendency to equilibrium consequent on the law of radiation, proceeds towards a very different result, and it must be perpetually counteracted by the production of heat in the earth. Did this not occur, the event would be the final loss of that average temperature indispensable to its existence as the support of a

living creation. Hence must heat be produced, in some manner, to replace that which may be viewed as utterly lost by radiation. We must presume that it arrives hither from the sun : not seeing that the internal heat believed to exist within our globe does reach its surface, except under actions too rare and partial to serve this purpose, and knowing that all else consists in changes of distribution. That radiation is also an aid to the conducting power, in producing useful inequalities and compensations, it should now be superfluous to say ; while it thus becomes an integrant portion of the mechanism just noticed.

Of that mechanism, however, I have given but a very general view : there is far more, on which the practical and useful effects depend. It is evident that the valuable qualities of these two laws must have produced many evil effects, had their actions been the same in all bodies, had they been universal, unlimited, and unmodified. Heat could never have been at rest ; it could not have been accumulated or retained anywhere : the whole earth and all that it contains would have been perpetually approximating to, or reaching, an uniform, and therefore a low temperature, notwithstanding the inequalities of production that exist. It was necessary therefore to modify both those laws by means of secondary ones, or laws of exception : and these, numerous and varied as they are, form a most interesting inquiry. But, minute, often abstruse, and, as yet, very insufficiently known, they form a subject far too extensive for this place : and I can here only point out to those who know or desire to study the history of heat, how they ought to be viewed. If the whole bears the marks of profound wisdom, it also belongs to that

wide class of design, where, after the establishment of a general principle, foresight the most perfect has been exerted to render it universally applicable, even to numerous discordant ends. And if creation were thus studied more widely, it would form a far other object of attraction than it seems to do at present. Unfortunately, it requires that philosophical spirit of generalization which is so rarely cultivated, or rather is neglected, in forgetting to call forth and exert the thinking powers. Such is one result of pernicious systems of education, if of education they can be called, which inculcate that knowledge is to be attained by reading, and variety of knowledge by the accumulation of facts in all its departments.

With respect to the conducting power, the most interesting circumstance is the structure, or mechanism, in bodies, by which it acts, acting also under such inequalities. I have already remarked that it bears no proportion to density or specific gravity: in reality, we can found no general ground of judgment at present, notwithstanding the instances, in cork, feathers, and so forth, which seem, at first, to support such an opinion. As yet, we must be content to receive the whole as a profound and complex invention, intended for useful purposes, as it is successfully applied to those: nor ought we to doubt the design, when we see the valuable applications that are made, in the clothing of animals, in the checking of subterranean heat, and in far more. All through creation, I repeat it again and again, nothing is accidental, or undesigned; there are no casual substances, or actions, as casually turned to good ends, —no things which might have been other than they are, and still! have produced the ends which occur, or ends

as good. And he who will bestow on these subjects the thought and the labour which are necessary for every scientific investigation, apart from all reference to their Author, if such be his inclination, will everywhere find a system of profound arrangement, of foresight and intention fulfilled by wisdom and resource, and organized on the purest principles of philosophy ; from which if he does not draw the obvious conclusion, it is not his logic, but something else, which is in fault.

Of the facts to illustrate the utility of the laws regulating the conducting power, I have noticed some in the 23rd chapter, and in speaking of the clothing of animals, in the 57th. If I just alluded to the checking of subterranean heat, it is to the non-conducting property of rocks that we owe this security ; while the rapid ratio in which the conducting power diminishes in these substances, enables a small depth of rock or earth to become an insurmountable obstacle to the progress of this agent : whence the deeper parts of this globe may be in a state of high ignition, notwithstanding the low temperature of the surface. It is thus also that we are enabled to manage and retain heat for endless uses : the non-conducting body is the wall by which we imprison what we would restrain, or regulate what we would direct. But I have no space to pursue illustrations which a little knowledge will easily suggest.

Similar modifications and exceptions occur in the law of radiation : but while we are far from knowing all the purposes, we are, as yet, but imperfectly acquainted with the facts. In the same chapters, I have noticed some of the applications and uses, as this law is brought to bear on the diffusion and the production of heat :

but I may restate some of the broader essential facts here, as they were not there brought under one simple aspect. An animal is hotter than the surrounding medium; and thence it must lose heat through radiation as well as by the conducting power. For this reason the law required modification: and this, as in the other case, has been effected through particular substances, and, still more remarkably, through surfaces, and through colours also. The power itself is so mysterious, that the difficulty is scarcely increased by finding that mere colour, without assignable change of texture or surface, should possess a modifying, or restraining force, or should, reversely, become the very cause of radiation. At present, we can give no reason but the end, the final cause: the service was required, and it has been given in charge to colour, or the cause of colour, to execute it. It does happen, in the case of animal furs, that the property of non-radiation and that of imperfect conducting are united: but there is no necessary connexion; it is a purely arbitrary union in this particular case, that the desired effect may be secured. Polished silver is a non-radiator, but among the best of conductors. Nor can we see any *à priori* reason why one colour should radiate better than another: but under a subsidiary law which we must equally deem arbitrary, the great purpose derived from the summer and winter clothing of certain animals is obtained, as analogous uses are extracted for the dark and the fair races of man.

But I must dismiss a subject which has occupied volumes. The illustrations are beyond numbering: yet I might not better prove, by the whole, what I have here attempted through a very few. The view which I

would willingly have given is the business of natural philosophy: and if it is still a claim on that branch of science, the cause must be sought in the omission of that High reference which forms the basis of this work, and in the neglect of that design, those final causes, which form the best, and often the only, grounds of generalization: as they also excite the attention, and add an interest which all should feel, to the often uninteresting details of mere science. Natural philosophy has been deeply in error, in thus excluding the Supreme cause, His plans and purposes: thence meeting, in even its confined pursuits, the appropriate punishment of its neglect.

CHAPTER XXXVI.

ON LIGHT.

IF the Creator had produced nothing more than Light, this alone would have been abundant evidence of His incomprehensible power, for, like Himself, it is incomprehensible. If, as philosophy supposes, it be a modification of matter, it is the most wonderful one which has proceeded from the Almighty hand; a perpetual and hourly miracle. It is not surprising that poetry has represented the Deity as dwelling in light, as light itself. It is at least the emblem of His all-pervading presence: affording a physical illustration of His attribute of Omnipresence. It possesses a central existence, yet it is everywhere, in all space, and almost at the same instant of time. It even passes through solid bodies, and is the cause through which we see that interior which we cannot touch. Much more then may the Creator of light be everywhere, and fill all space, though He were the central Existence which some have imagined: and equally may that Spirit pervade solid matter, when He has given this power to a creature, to that which is not even mind. If I have elsewhere remarked, that, to Him, the interior of bodies is as perceptible as the exterior is visible to us, the illustration is here. If poetry has also embodied its angelic forms in light, it has conformed more nearly to science

than it usually does when exerting its powers of imagination. If the Deity does attach life to that minute atom of matter which I have deduced by a process of exhaustion in another chapter, there is no conceivable minuteness or form to which it may not be attached, and, with it, mind. Thus might a spirit be embodied in even an elementary particle of light, were it necessary that it should be embodied : and thus might that rapidity of motion which poetry has attributed to its angelic natures, be a mere physical fact, instead of the poet's wild dream. Let not an illustration however be mistaken for an hypothesis : such speculations are of value if they can excite the imagination to that expanded reach of thought which the continuous statement of physical facts is for ever tending to check or destroy.

Compared to all else that we know, this power, the soul and the life of the world, seems to possess a spiritual rather than a material nature. Imponderable, intangible, incapable of being arrested and accumulated, ever under the most rapid motions though we cannot discover a projectile force, coming we know not how, and vanishing we know not where, it is, in all but the power of thought, a spirit : it is that existence at least which conveys to us the best idea of spirit as contrasted with matter ; of something really possessed of a being, instead of that which, as implying mere mind, we can never grasp, and are obliged to consolidate by a metaphor derived from a material object.

The prevailing hypothesis considers light as a species of matter, believing also that it can exhibit proofs : we shall immediately see the difficulties which attend it. There is a more recent one which supposes that it is

produced by motions in a hypothetical ether : and, in this, the difficulties are still greater. Science, here, as usual, is trammelled by the mechanical philosophy, without perceiving it : while neglecting also a fundamental fact in the history of mind, which even metaphysicians have forgotten to point out.

We possess but two terms, as I formerly suggested, matter and spirit, to include everything in the universe ; and, as thus contrasted, they are more truly terms than ideas. Of matter, we know some properties through our senses : but of its nature, abstractedly, we have no idea. Our consciousness assures us of the existence of a power capable of moving or otherwise influencing matter, as our reason infers a superior power similarly commanding it, but far more extensively. This is spirit ; of which the only definite idea we can form is, that it is thought and power ; while condemned to use a metaphorical term derived from matter, and thus, in reality, ever speaking of it as a substantial entity, and not as a power, the cause of matter, its properties, and its actions. Hence must our philosophy be inevitably regulated by those two terms, or ideas, such as they are.

Under one or the other, we must classify all the existences of the universe : and thence whatever is not spirit, in the pure sense of that term, must, in our language, be matter. And that language is the measure of our ideas : they cannot exist without it, for by it alone they exist. But that which is a dilemma to us may not be one to the Creator. It will be a sounder philosophy which admits that He has created existences that we cannot comprehend, and which is therefore willing to confess its ignorance ; while if light, or heat, or aught else, be of these, it is plain that we can never

attain the least conception of their nature, from the limit which He has fixed to our capacities, so that it is vain to endeavour to think on those subjects. This is that confession of the ignorance of science which I have often been compelled to make : let those who are unwilling to join in it, ask themselves if they are satisfied with their own imagined knowledge, and whether they have not long received fictions for truths, and insufficient hypotheses for valid theories.

But, granting that light is matter in motion, there are two hypotheses, as I just remarked ; and I may first note the most recent. There is a material elastic fluid, an ether, occupying all space, and light is the result of an undulatory motion in it, caused by the solar orbs and other bodies. If that ether was originally a purely hypothetical invention, its existence is now said to be proved by the retardation of a certain comet, termed that of Encke. Considering the difficulties of the observations in this case, with their yet solitary nature, philosophy would scarcely have been satisfied with such evidence, had there not been such an object as the present in view : and it is also believed possible that the planetary atmospheres may so extend through the solar space as to produce the effect in question. And if the applications of the hypothesis of undulation are imperfect and unsatisfactory, a sufficient number of objections will occur in the course of the following remarks, while it is not the purpose of this work to examine the speculations or theories of science.

Presuming, with the other hypothesis, that light consists of matter under projectile motion, the views adopted are those of the corpuscularian philosophy : the obvious vulgarity of which is deserving of notice,

if never remarked, since it applies much more widely than to the present case. Because the sense of touch furnishes us with the only real evidence of matter, we associate the notion of tangibility, which is extension and solidity, with all its forms, actual or possible : and though it escapes our senses, we continue to hold by this impression, and thus go on reducing the dimensions of its parts till we arrive at the hypothetical solid atom. Whatever convenience this may have afforded to mathematics, and whatever truths may have been elicited from it, our notions are not the more true. Assuredly, we can form no other idea of matter, because there is but the sense of touch through which we can receive one : but we forget that we make our limited senses the measure for the power and conduct of the Creator. We may avoid certain difficulties by the infinitesimal reduction of its parts ; but they meet us with equal force in another quarter, as I shall soon show. It is better to admit our utter incapacity to judge of that which the Creator has not given us the means of understanding. Let light be material, if it must be so to us, for want of other ideas : and we can still study its properties, though we refuse the hypothesis, which I shall soon show to be untenable on almost every point. My purpose will be equally served ; for it is through its difficulties and mysteries that we shall best view the incomprehensible power of God.

Light is imponderable, as far as we know, and should therefore be without gravitation. This appears a fundamental difficulty, if it be of a material nature : yet there may be an exception to that general law. Gravitation is a law of utility, or an arbitrary appointment of the Creator, for a special end ; or probably, it is His

own hand acting on bodies which could not otherwise have performed their offices. I have shown that it is unequally allotted to different substances of equal dimensions, and for specific purposes: whence we can conceive a body, or mode of matter, from which it has been withheld, presuming that it would have counteracted the duties required from that body. And light should be this substance, assuming that it is matter; because it could not otherwise have quitted the powerful attraction of the sun. To refuse this, is to say that gravitation is a property inherent in matter: an assertion which no one, claiming to be a sound philosopher, will now make. Light therefore, thus viewed, is an exception to a general, not a universal law; and general for certain general uses. This argument, attempting to reconcile the materiality of light with its want of gravitation, is the argument from final causes, under the design and will of the Creator. It is seldom well received; but it will not appear so unreasonable, when philosophy shall ask itself why all matter must gravitate. All its properties were appointed by Him who created it, and there is no necessity but His will; while that will was exerted for the attainment of specific ends. Philosophy is for ever entangling itself in nets of its own weaving, because it will not inquire of Him who designed, of the First Cause, and of His purposes.

Yet there is a weighty authority against this view, which must be answered. La Place supposes that a solar body may exist, so powerful in attraction, that even light would not quit it, or would quit it, but to return again. If this supposition rests on the very assumption in question, so should it be explained how

light could be propelled where the attraction was greatest, to return where it was least. And if it circulates in ellipses so long that the portion intercepted between the sun and the earth does not sensibly differ from a straight line, this also being used to account for the perpetuity of the sun's light, we must ask, what are the ellipses which circulate the lights of the remotest stars of the universe, so that the corresponding portions are also straight lines. This is to invent incomprehensible hypotheses in support of an original assumption: it is beneath the dignity of mathematical science.

The inflection or diffraction of light by solid bodies has been supposed a proof of its materiality, and its subjection to the laws of gravitation: and the fact of its refraction has been equally explained by the attraction of the substances through which it passes. In the first case, it seems to be forgotten that bodies are attracted in proportion to their quantity of matter, while the attraction is here very great, and the matter unassignable. And, that there is no necessary relation between ordinary attraction and gravitation, is apparent in the cases of electricity, magnetism, chemistry, and muscular action. And diffraction cannot prove the materiality of light, and has in fact no relation to material attraction; since it is the same whether the diffracting, or inflecting bodies, are solid masses of matter, or mere lines, such as the edges of a dark-coloured substance, applied to glass. It is the aperture alone which acts. The undulatory theory may offer an explanation; yet this will not suffice to prove its truth, against all the objections to which it is liable. In spite of great mathematical ingenuity, science has not been more successful under the case of refraction: while all that

we can at present conclude is, that these properties, like thousands more all through creation, are without necessary dependence on any other property, real, or assumed, but have been appointed for specific purposes. And thus much at least must strike us, even at this stage of the present inquiry. If light be something other than matter, it is a miraculous contrivance of the Deity : if matter without gravitation, it is not less wonderful : while, in either case, it is an exception to what we believe ourselves to know of the general laws of nature, as it is a splendid effort of His power.

The motion of light, (adhering still to the same hypothesis,) is the next of its properties demanding attention, as the chief circumstances of note are the velocity and the impelling power. The former much exceeds seven hundred millions of miles in an hour ; and, considered as the absolute transference of matter, is incomprehensible. Yet if it be so, it justifies what I have elsewhere said respecting the possibility of a system so faulty and untrue as the Ptolemaic, since the quantity of matter to be moved is indifferent. In the present case, we can see that a great velocity, at least, was needful, nor can we doubt that it would have been greater had that been requisite. This velocity can be measured for the light of the sun ; but not so for the other solar orbs ; nor has it been, for artificial or reflected light. A universal common velocity has been taken for granted ; though science should recollect that it has no experience : no cause of motion to produce, nor any law of motion ; since a single fact cannot establish a law. Hence this velocity may differ throughout the universe : as it will do should it be necessary, since the purpose of this or any other law is utility. Philosophy gene-

realizes till it controuls itself by its own rules: but it forgets that the Maker of rules for nature has not ordained them under systems of human invention, but that He might attain His own great purposes. If our light is propelled by an individual action of the sun, the propelling power may be as peculiar as the bulk or density of this orb, and thus may it differ in every one; while still more should this be true, could the hypothesis of elliptical circulation be established.

If this reasoning is but the questioning of an assumption, since it can be no more, it is not without a probable, or possible, bearing. There are obvious reasons why the light of the sun should reach all our planets in a very short time: it is not a long one even to Uranus. But if Lyra, under the magnitude which it is supposed to possess, is the governor of planets, bearing, in distance, a proportion similar to the solar ones, the same velocity of light would not produce the same results; and the law may differ. What may be the fact in the cases of reflection, and of transmission through other media than the solar space, or what the results of differences, if such there be, we do not know and cannot conjecture: but it is always useful to doubt the confident language of science, since it may lead to a pernicious credulity.

If such is the velocity of the sun's light, what is the propelling force, the cause of such motion? This is called the power of radiation; it is merely the same fact in other words. Motion, as far as we know, in matter, can only be produced by mind, acting directly on the body moved, or through the intervention of a previous body in motion. Metaphysics admit the one, and mathematics guide themselves by the other. Light

therefore, being supposed material, is moved either by a body in previous motion, or by the Creator's own hand: there is no choice, out of this dilemma.

The sun is ponderous as well as bulky, with a power of attraction sufficient to reduce under its command the enormous linear momenta of all the planets, as if they were tied by material chains. Whatever diversity of opinion there may be as to the exact seat of the sun's light, or the nature of its globe, the power of propulsion resides where that of gravitation does, while the latter does not neutralize it. The source of this motion must therefore be very powerful, since it counteracts one of the most energetic attractive forces that we know, even as if it were non-existent. That which, as matter, ought never to quit the sun, flies from it under an impulse which is incomprehensible: it is as if this great globe were not an attracting, but a repelling body. We cannot comprehend this; and though the wonder may be diminished by supposing that light is without gravitating power, there must still be a strong power of communicating motion residing, or acting, in the sun. The effort required to move a merely neutral body with such velocity cannot but be very great; while it is also unceasing, and ever acting with the same force.

The causes of motion that are known to us are few; and the nature of the case before us excludes gravitation, the attraction of cohesion, that of chemistry, and muscular attraction. The repulsive power of heat is an inadequate force; we are too ignorant of electricity to have recourse to it, and, as far as we know of magnetism, that source of motion is inapplicable. The only motion, moreover that we know, independent of these causes, is the centrifugal effort of the spheres: as, of this, we

know of no source but the hand which formed them. To that force then are we reduced in the case of light: there may be an intermediate agent; but for all that we can see, it is moved by the immediate hand of God. This would be true, even under the hypothesis of undulations: while if this one diminishes or removes any of the preceding difficulties, it encumbers us with equivalent or worse ones; though it is not here in my power, as it is not my duty, to discuss this, or any other of the numerous hypotheses of science.

Proceeding in right lines, under an ascertained velocity as far as the solar space is concerned, light traverses the atmosphere, and also the fluid and solid transparent bodies on the earth, still rectilinear in motion, with exception of such refractions as I shall hereafter examine, and presumed, but not proved, with the same velocity: while we infer, under the general laws of motion, that it must thus proceed for ever through space, unless the hypothesis of La Place be true. It is natural to ask, by what power, and under what form, it can traverse the bodies to which I have alluded, and especially the solids: being matter in motion, and these at least consisting of matter in a state of considerable density. There is no answer under this hypothesis: since no one can seriously believe in that insufficient theory of transparency which I have examined in the 38th Chapter, nor can it be explained under the hypothesis of undulation. It is indeed so obstructed, or affected in some manner, that it is at length lost; but the difficulty is scarcely thus diminished, since it should never have penetrated, while penetrating also at every infinitesimal point, as if the transparent body were nothing, a mere vacuity. I know of but one answer, under that theory which will never

fail us, whatever else may. This power was necessary, and it has been given by the Creator of light.

Setting aside the two hypotheses which I cannot re-discuss in every paragraph, it may now be asked, whither light goes in its ulterior progress from the solar bodies. Seeing it as it arrives to us from the most remote stars, and knowing that if there be a limit here, it is drawn by our own imperfect senses, we perceive that it is not lost or destroyed in space ; while, produced as it is from millions of suns, it can fail to accumulate, only because the universe is unbounded. But if thus produced as a material body, what is the progressive condition of these spheres ? The extinction of the sun has formed a jest against the hypochondriac : yet that which appears visionary may be true ; as this affords an easier solution of the disappearance of stars than the dispersion of their globes. Thus also we see that the creation of light is not necessarily involved in that of the sun as the great restraining balance of our planetary system : whence some obvious conclusions as to the historical records of creation.

I proceed to state these difficulties, because our ignorance proves the Creator's power as effectually as our knowledge evinces His wisdom. If light passes for ever unobstructed through space, thus for ever existing as such, what is its fate when obstructed, whether to its disappearance or not, but especially in the former case ? It appears ever flowing from the sun into a confined space ; there is neither escape nor return : and what material substance can that be, which, under no length of time, could fill that space so as to exclude a further addition ? Again, when that is filled, why does it disappear on the instant that a fresh supply is cut

off? The hypothesis of undulation has here less difficulty than its predecessor: but each fails too often for either to be true. It disappears on coming into contact with certain bodies; whence these are black. If a material entity, it is not destroyed, because no matter is destroyed: it is not reflected; and therefore is it thought to be absorbed. If this be the case, we cannot comprehend how such a body should combine with light during years or ages, without some accession of weight, however imponderable we may judge it as sensible light: unless indeed under the supposition that it is a non-gravitating matter. If the other hypothesis undertakes to explain this, it must also explain, how, in two cases of disappearance, absorption, or whatever else it be, one body termed phosphorescent, should have the power of exciting the luminous undulations, yet only for a definite time, and only after a previous exposure to similar undulations. The emission of matter previously absorbed, is at least a more plausible solution: but no hypothesis solves everything.

With all its velocity, light has no momentum: and the usual explanation given, is the minuteness of its parts. It is not surprising that such answers as this pass current with those who receive whatever is told them; the surprise is, that men pretending to mathematics can impose on themselves in such a manner, deceiving themselves by a word, when they see that all space is filled by these presumed particles, and admit that, in the case of momentum, the want of magnitude, or quantity of matter, is compensated by velocity. The difficulty is insuperable, under the material hypothesis at least: but this we can see. Such a consequence would have been evil: and the Creator has ordered that it shall not occur.

Every fresh difficulty furnishes us with a new instance of power at least, if we do not discern the wisdom everywhere, and are sometimes at a loss for the purpose. Light fills all space, and is present at every point of space, however infinitesimally minute: since there is no atom within reach of the sun's rays that is not illuminated. If it consists of atoms of matter, these must be separated by distances infinitesimally small: and this, under the corpuscularian hypothesis, is solidity. In that case it should possess momentum; whereas, having none, its minute atoms must be greatly distant, or, in the language of that hypothesis, it is the most porous of bodies. Yet this is but a commencement of difficulties, under the present view of light. All space, or some given space, such as the sphere bounding our system, is full of the light of the sun, because that body is seen everywhere. But it is similarly filled with the light of every planet and every star, and for the same reasons: or, while each of millions of lights can fill a space, or all space, separately, they do no more than fill it conjointly: nor does any one, or any number, thus occupying every point of space, prevent any other number from occupying the same places. The material hypothesis cannot explain that which wars against a fundamental axiom in mechanical philosophy: and whatever the other one may propose, such a complexity of undulatory motion as would be necessary, surpasses all conception, or rather, all possibility. Yet neither is abandoned by its supporters. The plain mind which is neither afraid to acknowledge ignorance nor ashamed to declare its belief in unintelligible power, looks to the Creator, and adores the Hand which for ever works this miracle.

But the miracle is even greater when we consider that all this light is in motion. That of the sun is ad-

mitted to be rectilinear in direction, and it therefore proceeds through all space, without obstruction. But the same is true of every luminous body. The lights from a hundred millions of stars are, for ever and at every instant, crossing each other in every possible direction; while each set of streams, from each of these bodies, fills, by itself, every point of space. Yet there is no collision. No assumption of infinitesimal minuteness in the particles of light will explain this; and if worse can be, the other hypothesis is still worse. All is worthless: that which was needed has been commanded, but the power of the Deity is, in this, as in far more, incomprehensible.

I have not noticed the speculations respecting the seat of the sun's light as related to that globe, seeing no purpose in them: and, having avoided the usual common-places respecting heat, shall barely mention those which relate to the sun, lest that which others have thought important should seem to have been forgotten. It is worse than trifling, as I formerly remarked, (c. 23) to praise the wisdom which placed light in the centre of the system rather than in one of the planets. That which was to enlighten every planet could have been nowhere else: and to quote this as a special act of wisdom, is to suppose the possibility of the Creator's deficiency in that thought or knowledge which was essential to the ends He had in view.

The reflection of light is productive of many similar difficulties, while adding new ones to the mysteries of this wonderful existence. It is returned from bodies with the same rectilinearity, and, as we believe, with the same velocity that it reached them: yet not from all bodies, nor, equally, from those which do reflect it.

The hypothesis explains this, and also the angle of reflection, by endowing it with perfect elasticity: satisfying itself, as usual, with words. But this elasticity vanishes under the slenderest alterations of the surface of the resisting body; being perfect from a white surface, and destroyed by a black one, though that body remains, in other respects what it was. It is elastic before the atmosphere, which offers the least resistance to its transmission: and thus without end; while it is an abuse of terms to compare this property with the elasticity of tangible bodies. If also light be infinitesimally minute, whence is it elastic, when elasticity is deemed to depend on composition of structure, and when infinitely small atoms are said to be unelastic? But if elastic only in the mass, from the repulsion of its parts, how is it reflected from a transparent body at one angle, while it is transmitted at another? Glass is elastic; it is high elasticity meeting with perfect elasticity: yet it transmits what it ought to reflect; there is no rebound.

But enough of objections easily extended. The term elasticity may be convenient in mathematical computations, as is the hypothesis of undulations, and they may still be used to discover truths: but let not symbolical language be mistaken for facts: the rebound of light is not the elasticity of mechanical science. And the source of motion is as mysterious here as in the case of direct light: we must have recourse, as before, to the Creator's will, and the final cause. If to this command we owe the utility of the moon, and much more, so do we derive far more important benefits in the case of atmospheric reflection: while I may here note this one as offering peculiar difficulties. This substance, containing, as a gas, the smallest proportion of matter amid all

the forms of bodies, reflects light, and transmits it also, at every point, and in every possible direction. These are opposing properties: it is a mass of contradictions: yet they are reconciled in some manner, and all the ends are gained, because it was necessary.

Were it not for this power and this mode of reflection, we should derive little comparative advantage from light as the medium of vision. Thus would a chamber receiving the sun's rays through an aperture, be in darkness in every part but that of their course; as the same evil would obviously prevail far more widely. Thus also would the light of a cloudy day be far less than it now is, though the clouds do not check all the rays, and though they also disperse them by refraction. But not to pursue obvious illustrations, the interesting general fact is, that reflected light performs all the offices of direct light, as far as vision is concerned. Thus is reflection that beautiful invention, if a secondary one, which is not less important, if less wonderful, than the original production and motion of light; since, without it, the ends intended by this creation could not have been attained.

Hence it is that light is rendered ever active and present, the universal medium of communication, even when parted from its source. And it is an instance of contrivance under wisdom. A law was appointed, efficacious under certain circumstances: interfering ones were foreseen, and the means of correction were required; whence a new law is made, to check this interference and aid the original ones. It is a compensation on the most magnificent scale, and the remedy is perfect. But I must defer the further consideration of this subject till I speak of vision, since the chief facts refer to

this, the great purpose and use of light. Of the scientific facts belonging to this or the other properties of light, not many bear on the great question before us, while they are familiar, or can be found everywhere. I must confine myself to a few which concern utility for man ; under which, stands refraction.

This is so singular a law of light, and so apparently independent of its other properties, that, under our views, it ought to possess a special utility in all cases : since we are apt to forget that the least of uses is a justification of the greatest exertion of power and contrivance in Him to whom the least and the greatest are equal. I need not describe the nature or the rules of aught so well known as refraction ; while I have already noticed the insufficiency of the usual explanations.

The use which this property of light serves in the case of the atmosphere, is the most obvious one. It is the source of twilight, so valuable in the higher latitudes, since, united to atmospheric reflection, it is the cause of most important light for animals. If there was any purpose in giving the same power to water, and in a far higher degree, we have not discovered it : while I know not that we dare consider the refracting powers of all fluids as a species of necessity dependent on that law which was necessary for the construction of the eye. If such an opinion be admissible, we might then also perhaps consider the variations of refraction in different fluids as deriving from a similar cause : though it is more likely that there are, in all this, many purposes yet undiscovered.

The necessity or utility of refraction in the case of an organ of vision, is familiar ; as optics will describe the common facts that I need not. And we cannot doubt

that this was one of the great purposes intended by this law of light : while it is another striking instance in which two distinct ends are gained by one contrivance. The Deity might indeed have constructed a mere nerve, capable of seeing a picture, as, in some animals, there is such a nerve capable of discerning a spot of light : but He doubtless chose that which He considered the best mode, in that law and construction by which light is brought to bear on the nerve of vision in a more condensed form.

Having designedly spoken of special uses directed to man alone, from contrivances in creation, I may here point out that this law, aided or not by those of reflection, has enabled him to construct those machines which have given him an insight into the works of the Creator, at the extremes both of magnitude and minuteness, that he never otherwise could have attained ; as thus also he has remedied the casual defects of his organ of vision. This was a worthy end ; or rather, the ends thus accomplished are both numerous and important. That knowledge of Him and His universe which we have thus obtained is beyond valuation : while I may safely leave it to the reader to scan all the uses, direct and collateral, which are derived from optical instruments. Has he not revealed Himself to man through the telescope and the microscope ; and did He not intend this also when He established the laws of refraction ?

I must now name a property or law of light, of a more abstruse nature, the utility of which we have not yet discovered : though we cannot doubt that it has been appointed for some purpose, and the more so that it is not contingent, as far as we see, on the other laws known to us. I cannot however here undertake to

explain the nature of polarization : nor need I give an abridged account of that which optics will more fully furnish, when I can draw from it no theological inferences. This is not a work to teach nature or the sciences : its design is to show men how the works of creation and the laws for the conduct of the universe ought to be studied. It should have been a foundation for the education in facts : where it must now fail in this, its business is to guide the conclusions from those.

The dispersion, or decomposition of light, is the cause of all colour, or thus at least do we suppose ; and hence it is a wide source of beauty, as it is of uses not so obvious. If light, under its simplest property of causing illumination, is a wonderful contrivance, it is far more so under that dissection which proves it a compound, not otherwise to have been suspected. And, in this, we find those further uses for the properties of refrangibility and reflexivity which I purposely deferred mentioning before, as those alone would have justified these two laws of light. It is on these that the dispersion or dissection of light, simple in common language, but compound in that of science, depends ; while we must also admire the simplicity of the contrivance which separates the integrant parts of the solar ray, by merely giving them different degrees of refrangibility. What these parts are, or what the colours and their properties, I need not here say, since this belongs to the most common optical knowledge ; but here again we encounter another of the mysteries of this unintelligible existence. Under the usual hypothesis, the incredibly minute atom which constitutes light is a compound of other atoms ; of seven, under the most

generally received theory, still more incredibly small therefore, if this can be, yet possessed of the same leading properties as the entire atom, even to the filling of all space, and without collision or mixture; since bodies of all colours, of the seven pure ones, and far more, are seen from all points in the surrounding sphere, even as white ones are.

If the ancient hypothesis explains as little of the mystery of colour as of aught else, it must be hoped that they who explain it through undulations believe themselves, at least, to understand what they desire others to believe. But though either, or any hypothesis were true, as far as the dissection of white light and the properties of the prismatic colours are concerned, the essential difficulties all remain; since the colours of the bodies which surround us are, with few exceptions, produced in some other manner, which, though we use terms that are commonly received as explanations, remains utterly unintelligible.

Presuming, under the theory of the prism, that all colour must be produced by the dissection, or dispersion, of pure light, yet, in this, assuming what is not proved, it is under reflection that the dispersion causing the ordinary colours of bodies occurs; while, further, the light thus affected is most generally the feeble reflected light of the atmosphere, not the solar direct ray. This is the practically useful law: the dispersion of direct light alone, through refraction, would have served little purpose. Nor is the acting cause, or mode, more understood than aught else in the nature and proceedings of light. We know indeed that the surfaces of metals may be so affected, or roughened, by oxidation, and by mechanical means, as

to render them dispersive of colour, as we also believe that nature has used a similar process in colouring the brilliant birds, and some other animals: while, in flowers, as I have elsewhere explained, this is united with refractive dispersion through transparent spherules, and with that which is most difficult of all to explain, substantial or transferable colour.

But this theory of dispersive reflection through inequalities of surface deserts us immediately, and with it our means of explanation. To polish coloured steel is to destroy this power; but no polish affects the colours of the ten thousand bodies around us, while they also display them equally in the interior, wherever a new surface is produced, and whatever be its nature. Such colour too is preserved when those substances may have become fluid, so as to have entirely changed any disposition of surfaces, or even of interior structure, on which such a theory could speculate. Nor is this all; since that fluid may again be solidified, under a chemical union with other substances, while still preserving its colour; though we are sure that the textures or mechanical disposition of the minute parts differs in each case. Cochineal and its solution, carmine and the crimson dye, are familiar examples under the first instance; while silk, cotton, wool, ivory, wood, will serve for the second; involving the art of dyeing. It is but to add difficulties to what is already inexplicable, to point out that while a certain substance thus in solution will reflect and transmit the same colour, another will reflect a different one from that which it transmits. No theory explains this, or ought else. In the case of dispersive refraction, the particle of mixed, or white light, is separated into portions, proceeding under dif-

ferent angles, but all visible ; and the same occurs by reflection from divided metallic surfaces. But in the ordinary cases of reflected colour, one alone is seen, nor can the rest be found. The received hypothesis says that they are absorbed. This sounds plausibly, and has therefore long passed without examination : yet while it cannot be a fact, it is a phrase without a defined meaning. There is no resemblance between the cases of ordinary reflected colour and that from divided surfaces, as the least attention will show : while it would be still more fruitless to ask such a theory to explain the mixed and degraded colours, since this would be to inquire of reflections and absorptions under mixtures and modes such that the bare attempt confuses the imagination.

Such is the mystery of colour, and such our ignorance : yet it is thus stated but to exalt the Creator's power. He has gained His ends, but we know not how : should time teach us this also, it will be to add admiration of the ingenuity to admiration of the power. That the facts thus obscure are connected with the polarization of light, is not improbable : but it must be the work of time to ascertain the applications of a law, the mere nature of which is as yet only under investigation. Whatever be the proceedings, it is thus, by means of colour, that light becomes as it were embodied in matter : so apparently fixed and permanent, that we habitually view it as a part of their material composition ; while even science can scarcely divest itself of this feeling, when finding that it can transfer colour from one object to another, as if it possessed a distinct and substantial existence. On the purposes of this contrivance, so mysteriously organized, both for utility

and pleasure, it would be easy to dwell ; but as far as the latter is concerned, the little which I can venture to say is reserved to a future and fitter chapter (c. 47). Both are united in that selection which has tinted the blue sky and painted the green earth : but for animals as well as man, if for the latter most extensively, the great utility consists in the discrimination of objects. Mere light and shadow, the presence of more or less of white light, would have separated and disclosed single forms ; as thus we might still have known what we could not touch. But a vast mass of confusion would still have existed, for which a remedy has been appointed in colour ; justifying this intricate machinery on the ground of mere use, though beneficence has added to this, superfluous and pure pleasure.

Whatever other purposes light may serve, the great end is Vision ; that power without which we cannot even imagine a world of animals. For them, chiefly at least, it was created ; as to them have been given an organ and a sense adapted to apply and to feel it. We know of objects but through our nerves ; they are the medium of communication between mind and matter ; and it is by contact with a nerve that the latter is known to the former. In the simplest case of a sense, that of touch, the resistance conveys the idea ; in hearing, there is another species of resistance, through elasticity and motion, of some kind : in tasting and smelling, there is the contact of chemical substances which probably act as such, rather than through mere mechanical impulses. But in what manner, knowing those senses only, could we have deemed it possible to gain contact with the remote, with even the immeasurable and incomprehensible remoteness of the stars ? That we do this, is among

the greatest marvels of creation : yet we see them daily, and forget to wonder.

Light is the connecting medium between the animals of the universe, and the surrounding objects, with which they cannot come into contact, but with which they must communicate, if in different degrees, for indispensable purposes. The animal body is made to touch even the infinitely distant, by means of this mysterious existence, or power, transmitted from every body in the universe, even through immeasurable space, and with a rapidity which renders the contact of the remote sun almost as instantaneous as that of a substance within a few inches of the hand. A nerve has been prepared to feel the contact of light ; it communicates with the mind, which thus knows the object whence the light was transmitted, in its size, its colours, and its place, while that size and those colours tell its form. We have touched the object through a medium which communicates with it at one extremity, and at the other with ourselves : and it is more than the rod which enables the hand to ascertain a distant body, since it rather resembles a sensitive antenna, discerning qualities too delicate for even that hand itself to perceive. And the power of light is not only that of a nerve prolonged from our eye to the sun, or to the stars, but it is a universal nerve, in perpetual contact with everything that exists, or else capable of being rendered so ; and thus bringing every animal into contact with every body in the universe. Without light, there would, to us, be scarcely a creation beyond the actual reach of our hands : it is a hand which stretches to the incomprehensible limits of the visible orbs—which grasps every object in the universe : the link which binds us to all the works of God.

I know no mode so effectual for conveying the full force of a Divine intention, as that which I have so often adopted : it is that of supposing a problem to be solved. It was indispensable that animals should be aware of the existence of bodies which they could not touch : and we must, by an effort of imagination, divest ourselves of the knowledge that this is actually done. Even in the case of touch, we for ever forget that wonderful invention, the nerve ; and, accustomed to the collisions of insensible bodies, do not reflect that the object must come in contact with the mind. But even with this aid, how would man suggest the means of reaching the sun, removed by millions of miles, of feeling its colour and its shape ? Might magnetism suggest to him some general contrivance analogous to the existing one ? It may be doubted ; while if it did, he must yet invent the means of making it declare magnitudes and colours, as his machinery must never waver or weary, must interfere in no manner with any substance or any motion, must equally declare the truth respecting the point of a pin at hand and the remotest orb of the universe, and, though crossing that universe for ever, in endless millions of directions, must never interfere with itself.

This, and far more than this, is the problem which the Creator has solved, in all its parts. He has placed in the universe a substance or a power which so eludes our conceptions that we cannot even apply a term to it : acting nevertheless under a few simple laws, existing everywhere, and uniting the animal world to all things, even the most remote, so that they are enabled to feel every object in the surrounding space, and with an accuracy and extent of grasp which the sense of touch cannot approach. This is light, the most wonderful work of

Him whose every work is a wonder: though being allowed to form more accurate conceptions of some few, we too often forget their marvellous nature.

Thus is light the source of vision; as vision is contact, for all the required purposes. But, had there been no other than simple and direct light, it would have been no more than a rod of communication between the animal and luminous bodies: we should have seen little else than the sun and the stars. Much more was needful; and much more has been done, by endowing it with the several properties which I have already described. But I could not render the chief of these sufficiently impressive except through their connexions with vision; and thence must I note some particulars more fully than I have yet done.

If all bodies reflect light, whether direct or already reflected, so does it proceed with the same rectilinearity, and, as we presume, with the same velocity, after any number of reflections. The proceeding is the same from whatever source produced, or returned; and it is the same also for the several parts of dissected light, or for those particles, or rays, which are colour, and which, under some mode, are presumed to be the cause of all colour in bodies. Every body which is not purely black returns light of some kind, pure or coloured, from every point of its surface, in every direction: while the effect of contrast renders that otherwise invisible one not less distinct than those by which it is surrounded. There is an entire sphere of light proceeding, not simply from every body, but from every point of its surface, however minute: that minuteness being also infinitesimal, though the sensibility of the optical nerve constitutes the much lower practical limit. Thus

does every point of every surface emulate the sun, in being a propeller of light, under the same laws of motion; while that light fills a sphere, the boundary of which we cannot conjecture, as we know that it cannot be a given animal eye: it may be that of the universe itself, for aught that we can decide.

I formerly termed it a miracle that the light of the sun should fill all the universe, and that every light from every star should fill the same sphere: while this is not less true of the attendant planets, though producing only reflected light. This is incomprehensible: but if incomprehensibles could be subjects of comparison, it is nothing, compared to the fact before us. In the midst of all these spheres of distinct lights, all coexisting, and each filling all space, there is not a superficial point or particle of matter in the universe, which is not, equally, the centre of a distinct sphere of light proceeding from itself: these myriads beyond myriads all coexisting even as the lights of the solar bodies do, each one perfect in the midst of all the rest, each one filling all space from endless centres dispersed all over the universe, and not one interfering with any other, or impeding its perfect form or existence, or its qualities, where these spheres are formed of coloured light. Millions of spheres, under thousands of colours, are, all and each, as perfect as if the universal space was occupied by a single tint. The mind can form no conception of such entanglement, such a complicated coexistence, and where all space is full of each sphere, even as light fills. Far less can it do this when it considers light as a material substance, a collection of solid particles, dilute or dispose these as it may: while if it can better succeed under a theory of undulations, plain minds would gladly

see how mathematics can extricate themselves from the least difficulty, under any refinement or deceptiveness of calculation. It is that miracle which, unknown, we should pronounce to be an impossibility, even to Creative power.

The reader who has never reflected on this subject, or who has only seen what is usually written on light and vision, may perhaps be surprised at this statement. He ought to be satisfied that it is true; but he ought also to reflect for himself, that he may feel the full force of this miracle. At every point in space the eye sees the visible object: seeing it also through a ray of light proceeding from it to the optic nerve. Every visible point is thence the centre of a sphere of that light which it propels, or radiates. Let him, therefore, surveying the landscape before him, first count the objects, then estimate the visible points on each, and lastly their places: when thus he will learn to conceive, as he best can, the centres of as many spheres, and the spheres themselves; and convince his reason, feel as he may, that the statement which I have given is true, however marvellous or incredible it may appear.

If I dwell on some other circumstances, most of which have already been slenderly noticed, it is not for the purpose of augmenting the difficulties or exposing our ignorance, but of increasing our admiration. The spheres of reflected light, sometimes variously coloured, at others pure, are often extremely feeble in illuminating power, and therefore should consist of a small comparative quantity of this matter, or whatever else it be; while we must use this language for want of better. Yet they are unaffected by the more powerful direct lights amid which they exist: the sphere, for example,

which is radiated from the grey body of a few inches in diameter, or from a single point on its surface, being undisturbed by that one of which the sun is the centre, just as spheres of every colour that flowers can produce, and more, are uninfluenced by the great investing sphere of blue light, even should the radiating surface be no more than the anther of a rose. And the fact of non-interference must be much more striking under this view, than from merely considering the direct lights of the solar and other bodies; since, whatever hypothesis be adopted, that of actual streams, or of undulations, no imagination can follow either, when seeing that there is not a visible point in space, whether radiating direct or reflected light, powerful or feeble, white or coloured, which is not the central point to an unbounded sphere of rectilinear motions performed with the velocity of light: while, thus crossing each other's paths in directions which it confuses the mind to think of, and not one of these incalculable millions leaving any vacuity in space, there is neither collision nor interference. Matter, as it is known to us, or tangible substance, may divert light from its course; but no light deflects light. And undulations, whether in water or air, impede or even destroy each other; if indeed the latter can be admitted as the cause of sound. In both cases, the vulgar foundation of this mechanical hypothesis is apparent: but however it may fail in that of sound, its failure in the case of light is far more signal. I need scarcely remark, I trust, that inasmuch as one light destroys a weaker one, to our senses, it is a fact depending on the sense of vision: all lights exist together, but all are not seen.

I already stated, that under the most received hypo-

thesis, the co-existence of the lights of two or more solar bodies must be a case of matter penetrating matter, or of two bodies present in the same place, and thus mathematically “absurd.” But this “absurdity” is enhanced beyond all imagination, under the views held out in the preceding paragraph; since the same infinitesimal point must be occupied by incalculable millions of infinitesimal particles; as, under the other hypothesis, it would be the seat of similar millions of undulations, and all proceeding in different directions.

I remarked, further, that if the light of the sun, for example, filled all space, its particles must be everywhere in contact, since no point is anywhere unilluminated: which is, according to the atomical doctrines, to be a solid body. But being whatever it may at the distance of even Uranus, what is it near the body of the sun? It is in reality more dense, if such a term can be used, near the radiating body, than at a distance; since the power of illumination is greater: but what can that be, which can occupy either a cubic inch or a cubic mile, equally filling both, which in its state of greatest density admits any other number of equal quantities of the same within the same space, just as in its state of most dilution; and which, moving with its admitted velocity, obstructs another and similar one no more under its greatest density than when most dilute? It is as if light were nothing; a mere power in the nerve of sight, or a deceptive vision, making us believe in what has no existence.

The reader can imagine to himself more than I need now urge or restate: but I do not say wrong, when I say that the difficulties in the theory or history of mind do not exceed those which belong to light: they are

equally incomprehensible. And thence perhaps might we learn a lesson of modesty in speculating beyond the reach of our powers, and in refusing to believe what we cannot comprehend. The commonest physical facts in creation are so full of contradictions to us, and so inconceivable, that we should pronounce them impossible but for that conviction to experience which compels belief: the blind would say that vision, the contact of a distant body with the mind, could not be effected in such a manner,—that the construction and government of light, as I have described it, was impossible even to the Deity himself. Here then is one of the least of His works, which we do not understand: yet we presume to limit Him in things that may even be more easy than this, (could there be comparative facilities to Omnipotence,) as if we could define the nature and extent of a power, which, under one of its most common efforts, is incredible, otherwise than as our senses compel us to admit it.

Such is the machinery provided for the communication of animals with distant bodies; which might indeed have equally existed though there had been no eye to profit by it, but which would then have been without apparent use. And the optical apparatus of the eye is so contrived as to condense the light proceeding from an object upon the sentient nerve, which proceeds to communicate what it feels, to the mind. This is vision: it is the feeling of light under all its modes; a sense of feeling so refined as to perceive a contact which impresses no other nerve. The nature and action of the eye was formerly described, and is indeed familiar to almost every person. It receives a picture of the external objects, as we can ascertain by inspection.

But it does not create that picture : it only arrests what was pre-existent in light ; painted on light, if I may use such a phrase : and thus may we consider all space as everywhere filled with the pictures of everything, and the picture of every object at every point of it. Thence does the eye touch those pictures wherever it is placed : while if there is anything which it does not feel, or see, it is because the power of its discernment is limited. There is no limit caused by mere distance, since the stars are seen at immeasurable ones : the strength of the impression is the only limit, and this is regulated by the intensity, or quantity of the light. Thus an incommensurable point is seen in the case just quoted, because of the quantity of the light : a much larger dimension in the object is necessary if the light be reflected, and feeble, or dilute. But in each case alike, it is the power of the nerve which is the real limit : and thus we can conceive a nerve capable of discerning what is now invisible, knowing indeed that there are optical nerves of higher powers than our own, as we also supply the deficiency of power by optical contrivances which enhance the power of the eye in collecting light from the object radiating it in whatever mode. Hence might we conceive an eye capable of seeing much further beyond the boundaries of the universe, as our own eye fixes those, than we do, even with optical aids ; since we cannot decide on the possible extent of nervous sensibility : nor would it be violently extravagant to imagine beings capable of discerning, at the distance of two planets, even more than we do in the moon, since we can scarcely say that this would be contrary to the course of nature.

I must however quit subjects on which a reflecting

reader can still suggest much more than I can here afford to say, and proceed to notice, though but briefly, such other uses and properties of light as seem to be known, together with the remaining sources whence it is produced, in as far as these have not been discussed on other occasions.

If we except the Truffle, some Byssi which grow in caverns, and possibly a few more, it seems certain that light is indispensable to the very existence of plants: it is undisputed that it is essential to their well-being, and apparently in even a greater degree than to that of animals, independently of its uses to them for vision. We do not however know in what manner it acts on plants: but we can see that they are sensible of its presence, that they make great exertions to procure or enjoy it, and that without it they languish, and at length die, under an evident depravation of their chemical energy, or powers, affecting their constitution as well as their secretions. In proportion, reversely, to its presence, and quantity, or energy, is the perfection of their productions; whether these be superfluous ones, or essential to their healthy existence and the continuation of their races. Such are the leading facts: on the actual results I have no room to dilate: as they also ought to be generally known. Thence has light been termed a stimulus to the vegetable powers: which is simply using another term to express the same general fact; though it is the solution with which science appears to satisfy itself, on many more occasions than the present; as if a change of terms were the explanation of a cause. If natural theology can at present do no more, it can at least admire the wisdom which attains very distinct purposes by one contrivance.

That light produces certain chemical effects on some inorganic bodies, is a general expression for many distinct facts in chemistry, the exact nature of which we do not know, while also we do not discover the uses. As I can apply these to no purpose under the present views, I may refer the reader who is desirous of being acquainted with them, to the well-known books on that science.

Of the sources of light independent of the celestial bodies, the great one, to us, is combustion: as, on this, I have already had occasion to make some remarks in the last chapter, superseding what would otherwise have been needed here. The utility is familiar; the mystery, like all else which belongs to light, is inscrutable. Two substances, or elements, unite into a new compound under the action of heat; when light appears, possessed of the same general characters as when proceeding from the sun. It radiates similarly from the point of production, whether through some power of its own or of the producing substance, is unknown: though this common fact may lead us to doubt any theory which supposes the power of propelling light to reside in the solid globe of the sun. It also proceeds with similar velocity, though we cannot prove that it moves with the same: interfering with no other light, and being reflexible, refrangible, and so forth, as solar light is. It is very rarely, however, white, or colourless: consisting, in almost every case, of the integrant parts of white light, united in different proportions as it proceeds from the combustion of different bodies. We may here ask the usual questions to which our ignorance compels us. If this light is matter, where does it exist, and what is its nature when dormant: if motion, in what manner

can the union of an atom of oxygen with one of hydrogen, or with three, or with twenty, were the fact so, excite a sphere of undulations throughout all space? To this, and more, science has no answer: for the tenth time, every hypothesis must be rejected, not simply by the plain sense of mankind, which, in matters of science, is not always a competent judge, but by mathematician and metaphysician and chemist; provided it be not he who is the fabricator of the hypothesis, or its abettor, under indolence, prejudice, or blind submission to authority.

I have already stated our ignorance of the course of the light under electricity; and need but enumerate it here among the rest. The various cases of what is loosely termed phosphorescence, whether produced by heat, or by friction, or by chemical actions, or by what appears to be an absorption with and subsequent emission of light, are all equally mysterious: and, affording science no clue towards a better knowledge of this subject, so do they offer nothing more to natural theology than it has already deduced. These sources of light are even without utility, as far as we yet perceive, except in the single case of the phosphorescent animals, as they are termed; while I have described that of the marine ones, with the great uses to which this property is applied, in the 27th chapter.

CHAPTER XXXVII.

ON CHEMISTRY.

IF the power of the Creator is peculiarly displayed in the mechanism of the great universe, so is it there demonstrated with more facility than under any other of its effects. The bulk of the great bodies of which this is constituted, their numbers, the extent which they occupy in space, and the forces which gave and which preserve their motions, are such that we cannot think of them, even in the slightest manner, without shrinking into ourselves before the immensity of Him who produced all this and regulates it for ever. It may indeed be true, that the full force and extent of this impression are confined to philosophers ; since philosophy alone can produce the demonstrations and make the due inferences. But there is much also that can be felt by every one. The bodies themselves are visible to all ; and so are the motions of the most remarkable. It scarcely even demands reflection to produce the desired effect ; since every one can comprehend space, magnitude, number, and velocity, by mere reference to familiar standards.

The power, then, at least, of the Creator can here be appreciated and felt, even by ignorance ; if, to estimate the wisdom demands knowledge. And that power is displayed in different modes. It required power the

most incomprehensible to create all this matter from nothing: it required power to construct from it those immense globes, in all their variety of forms and dimensions and properties, to place them where they lie through the extent of immensity, to communicate to them their various motions, and to preserve those by that further and perpetual action which, from its regularity and permanence, we term a law. If these forms of matter constitute the body, motion is the vital principle, or soul, of the universe of orbs: and if the former proceeded from a temporary or transient act of the Creator, the latter is His unceasing influence, a demonstration of His perpetual exertion of power.

If, now, there were in nature but one form of matter, or matter alone, in the abstract sense of that word, we could acquire no further knowledge of the wisdom and power of the Creator than might be derived from the great universe. Or, if man could exist as mere mind, in a world of solar and planetary bodies alone, consisting of abstract matter, the demonstrations of His power would be limited to the existence and the motion of those globes, and the proofs of His wisdom to the provisions for their regularity and duration. Under such an imaginary case, we should know nothing of matter but as a something under which the great mechanism proceeds. It would have possessed centrifugal and centripetal forces and movements in its portions, under certain regulations constituting its laws of action; but of what nature it might have been, what other properties it might have possessed, we could have formed no conception: if indeed it had possessed any.

But no such thing as abstract matter is known. We see it but as under various aspects, forms, or properties:

nor can we conjecture which of all these approaches most nearly to the metaphysical notion of matter; otherwise than as we can exclude a considerable number, under that Chemistry which we have investigated. Such is the constitution of the inanimate globes, as well as of the organized bodies possessing vitality; and, in each department, equally, we can ascertain that many of the obvious forms are compounded from two, or more, which are therefore simpler ones; because we can perceive, and even produce, both the separation and the union which occur in the ordinary course of nature.

If some of the existent forms of matter can be separated into three or four, others are divisible but into two; while we also obtain forms that we can divide no longer; possessing the further power of uniting these, so as to reproduce the original ones. To us, therefore, these are primary modes of matter: and should they prove to be truly indivisible, they must be matter itself; speaking rigidly and physically. And should this be true of any number of the indivisible substances, though the state of our knowledge will not allow us to assume it as true of any one, it will follow that there is no such thing as matter in the abstract, but that the Deity has created different matters, or substances, of peculiar and distinct properties. He may not indeed have done this: but whoever chooses to suppose that He has, thus proposing a new hypothesis, is at least as safe as the philosopher who assumes a fundamental matter, modified into the several assignable forms. The term "modification" is sufficiently ill chosen; especially by those who, as metaphysicians, profess accuracy of language, desiring to use none as the expression of a fact which does not actually express it. In what sense can

“modification of form” be used, under the hypothesis of an ultimate form, or atom; of the Monad? The idlest dreams of the corpuscularians, under which spiculæ of cold arrested the globules of water, are not more nugatory and infantile. And if there is any other sense attachable to the word modification in this case, they who use it must explain that, if they can. Chemistry can at least conceive that two matters, of different properties, can unite to produce a substance with a third property: but neither chemistry nor metaphysics can explain, or even comprehend, how one substance, of one property, shall, by any mode of composition, or multiplication, acquire a new property, or many new properties: how abstract matter, to recur to metaphysical language, can ever be aught but one thing: except indeed under the corpuscularian reveries to which I have just referred. The philosopher therefore who will not believe in abstract matter, stands even on safer grounds than the metaphysico-mathematician; since he is supported by some facts at least, while the other has none.

I do not say that this ought to be the hypothesis of a chemist, as opposed to that of mathematics, or that it expresses the truth in this case: yet it is what he must use as the groundwork of such reasonings as those which here follow. At least, let it not be forgotten that the term matter is a purely hypotheticalal one, that it is without meaning in physics, or expresses no fact. It is a mere symbol, the x of an unknown quantity; often as it is carelessly adopted and used, as if it were a physical entity, expressing a fact, or a thing. Its mathematical use is correct, because this is a science of abstractions: but chemistry must reject a word which,

lying out of its boundaries, may become a source of error.

The great question here before us is the power of the Deity through Chemistry. I must therefore proceed as if He had produced the substances which we cannot divide, as indivisible ones, or elementary matters: still admitting the probability of our ignorance. And as the general reader will conceive the nature of chemical union and separation, as far as is requisite for inferring an element, or ultimate mode of matter, most easily under the ancient doctrine of affinities, it will be best stated in this manner. If two elements, A and B, unite, the produce is a third substance, or a compound form of matter, capable of being disunited by the contact of a third element, C, possessing a greater force of adhesion to A; when a compound of A and C is the result, and B returns to its original condition. This will suffice for the present purpose. I need not enter on the facts or theories of chemistry: the more, that all who may read this chapter are likely to be acquainted with them. Our present ignorance as to the elements does not vitiate the Theological argument: and though it were proved that those which now appear such to us, were but modes of abstract matter, they would still be appointments by the Creator, offering the same grounds of reasoning as far as the present question is concerned: as that reasoning will also hold under any modifications which our knowledge may hereafter undergo. And if, as is probable, the progress of Chemistry should demonstrate a greater simplicity than we can now perceive, the result will be that which has already followed from our more accurate acquaintance with the celestial mechanism.

The first display then of Almighty power consists in the creation of so many different forms of matter; or in the production, in some manner, of the numerous elementary bodies which chemistry acknowledges, under all the remarkable properties which these possess. In those cases also which we have attained to know, we perceive the usual proofs of Divine wisdom, in the beauty and simplicity of the arrangements: the whole opening to us a new source of study under the evidences of Natural Religion: an endless field, compared to that of the celestial mechanism, where the energies of the Creator are, to our observation, limited within the comparatively narrow circle of mechanics and dynamics.

And if much of this last portion of nature is open to all, so is that true of the modes and actions of matter under the science of Chemistry. A multitude of familiar objects, possessed of various properties, surrounds us on all hands; and though the mass of their actions on each other constitutes a most abstruse subject, hundreds are ever occurring which it is barely sufficient once to point out, to render their nature and importance intelligible, even to the ignorant. The different qualities of the several metals and other familiar minerals, and of the ordinary vegetable and animal substances used in the arts, with the common actions of fusion, boiling, and evaporation, and the effects of mixture under numerous substances and modes, are known to every one: and thus can all, with little or no science, turn their reflections to the considerations in question.

But there is much more than this to be investigated by chemistry, and where the investigations are also of a very abstruse nature. The substances and their distinctions are often obscure: it frequently demands pro-

found attention to assign the ingredients and their proportions in the compound bodies: and in pursuing our researches after elementary forms, the doubts increase with the difficulties, while there are many which, whether elementary or not, escape our senses, as the want of agents checks further pursuit.

Yet is all this little, compared to the difficulties when this science attempts to investigate the nature and the causes of the motions among these substances. If mechanics include abstract matter and its motions, in large or assignable masses, so does chemistry also include both: but while both the matter and the movements are visible in the former case, the forms of matter which concern chemistry, together with the motions which these undergo, are equally invisible and unassignable; being indeed, at present, even beyond conjecture. We simply know, from experience and by inference, that there must be matters of many different kinds, unassignably minute; as also that there must be motions, because both the separation of a compound into parts, and its production from those parts, must comprise motion, and probably in different degrees or kinds. But whatever difficulty may belong to the substances with which Chemistry is concerned, its dynamics (to borrow this term) are at present utterly incomprehensible. They are the invisible motions of invisible parts of matter: and if the causes of those motions are unknown, so is it impossible to comprehend how they can be varied for the production of so many different effects.

It is in the dynamics of Chemistry, then, or the motions of invisible forms of matter, that we contemplate another great display of the Creator's power: more in-

comprehensible, we might say, than that which created the original forms, or elements, if the incomprehensible were a subject of comparison : because, as in the orbs of the universe compared to their motions, the one was a transient act, and the other must be a perpetual exertion of power, or the unceasing energy of the Divine mind. If also we compare the motions under Chemistry with those of the celestial mechanism, they offer a far higher subject of wonder, or, to us, of difficulty, as implying much greater exertions of power and knowledge. In the latter we may consider the centrifugal forces, like the production of the orbs themselves, as the result of a temporary exertion of power, reasoning on the hypothesis of inertia ; while gravitation alone demands the continuous action, or influencing will, of the Deity. Thus even this act of power appears simple, being under a simple steady principle, or “ law,” which mathematics assign. But, using the term attraction to express chemical motion, as a substitute for an unknown cause, we must infer, that as any one tendency, or movement, in a single element, is an act of power equivalent to gravitation, inasmuch as it is equally a distinct action, so must there be as many distinct acts of power, at least, be they termed inventions, appointments, or “ laws,” under chemical attraction, as there are elements, or as there are assignable forces of combination among the chemical modes of matter.

If this view has been made simple, so is it left imperfect, as thus affording greater facility to the reader in estimating the Divine power in this case. I cannot indeed give a correct one, because Chemistry is, here, still ignorant. But we are sure that is not the whole of the needful power exerted, and that the facts of this

science cannot be explained by mere differences of the quantity, or force, of attraction attached to each element. Repulsion must equally be assumed here, as in the simpler case of adhesive force: while if we know not its cause or nature, or its relation to ordinary attraction, in this instance, we are equally in the dark under the cases of chemical action. And though we should attribute the repulsive power to heat, generally, and the differences of this force to differences in the quantities of attached heat, thus rendering it unnecessary to suppose different forces of attraction, it is plain that we remove no difficulty, or that we substitute one for another. Under any view, power, as inexplicably as it is variously and widely exerted, must be granted: while chemistry must also confess that it is utterly unable to explain the nature of its action, on any theory yet produced. And if I name its most recent system of atomic combinations, it is plain that this is but the assignment of facts, not of a cause; valuable as it may be in relation to actual practice or the ulterior increase of knowledge. The difficulties remain as they were: and we continue equally ignorant of the means by which the Creator works in this case, in what mode He directs His great agent, Chemistry: while, unable to discover how those immense and multifarious operations are conducted, we must forcibly look, beyond all that we see, directly to Him and His power, to His superintendence and agency.

If Chemistry is a sufficiently marvellous power, even when its various products are viewed as the combinations of elements originally different, it would be a far more wonderful one if we could prove that there was but one fundamental element, or Matter, and that all

else consisted in the sizes, forms, or distance of atoms, under various combinations; since it would thus rank under that science of mechanics which, in everything else, is sufficiently simple and clear. But these corpuscularian hypotheses, under whatever variation, have been the produce of mathematics; increasing difficulties instead of solving them. Limited to one class of researches, mathematicians have misled themselves in pursuing their special idol: assuming that there was but one power in the universe, or neglecting what they had not studied. And if modern chemistry has followed them, influenced by the weight of names, and the too often magical influence of the term mathematics, it has not seen that it was bending to the yoke of an ancient hypothesis, which has attempted to explain everything, and has elucidated nothing. It may be painful to be ignorant, though the more usual pain arises from the consciousness of appearing so: yet ignorance is still preferable to that which is not knowledge; as, to be sensible of it is the first step in the road to truth.

And why must we seek any portion of the theory of Chemistry in mechanics? The necessity has been assumed, and the hypotheses have been fabricated accordingly: but the assumption is that of a remote antiquity, when the existence of chemical power had scarcely been suspected, and mechanics constituted the whole of physical science. It is time that Chemistry should know what it does not seem to have perceived, and break that chain which has equally fettered the philosophy of light and heat, nay, even of mind itself. A corpuscularian hypothesis, ancient, in some form, as even philosophy, has been erected into a reality; and, sanctioned by great names, has passed for truth among the followers of

authority : while even the former, finding that it could be used for extracting truths, seem to have forgotten that it was, still, but a mathematical fiction. If the beautiful simplicity of the celestial mechanism has been made the imaginary standard for all the Creator's works, and thus aided in misleading those men, I have often here shown that this hypothetical simplicity cannot be thus extended. Under the present inquiry, there are many other bodies, and many other properties than those of which mechanics can take cognizance, many other motions than dynamics can measure : and the Deity may yet possess many more agents than those which we see, if imperfectly. The power of Life, I have elsewhere shown, is an agent as distinct from chemistry as this is from mechanics ; and until the phenomena of light and heat shall be far otherwise explained than they have yet been by the mechanical philosophy, I, for one, must continue convinced of our utter ignorance respecting the proceedings of the Deity in these cases. Nor is this view without value as relates to a main purpose of this work. Every Epicurean system has been based on the mechanical theory, be its form what it may, as the physical arguments also for the non-existence of matter hang on it : to shake its hitherto all-engrossing power, is to deprive philosophical atheism of its great stronghold.

Such is all that I feel it necessary to say on the mysteries of Chemistry ; on what would be its theory, if a theory had been understood or assigned. The numerous writings on this science will supply all that I purposely leave unsaid, when my object is, solely to mark where the limits of what is known lie, and, in passing at once from this to the Deity, to show in what manner His

power appears to be displayed. And I must repeat, that it is far more strikingly demonstrated here than in the great celestial system : entirely as my predecessors have neglected this agent, and His power and action under it, while often dwelling, even to iteration, on the far simpler facts of "astronomy." If the celestial motions form the living soul of the extended universe of orbs, far more striking is the living and moving spirit of Chemistry, when each element, every invisible, incommensurable, un conjecturable atom appears to be actuated by a principle of life, even almost to possess a specific life, with an inclination, a will, of its own. It is a pardonable, though an inefficient illustration, to compare these, on each side, with the simple act of locomotion in an animal body, and with the millions of motions which pervade every atom of this living mass. Under mechanics, the masses of the sun, the earth, the planets, of suns and planets innumerable, may be considered to live, as they move : but under chemistry, there is not one inappreciable atom in every one of those immense masses throughout the whole universe, which is not ever alive, and ever ready to act, if not ever acting : implying a mass and a multitude of lives and motions, before which the others seem to shrink into absolute insignificance. And this is Chemistry ; it is the power of God under chemistry. It is an ever-restless universe of life and motion, in every atom, and, as ever moving, ever changing : a ceaseless round, and under rules as fixed, or laws as certain, as those which govern the equally unceasing round of the great universe, though we are as yet unable to define them. Complicated as they seem, and ignorant as we are, yet are they no more under the dominion of chance than those of the celestial bodies.

If there be an ignorance which could thus conclude, the minutest chemist can inform it, that the rules which he has ascertained are as fixed as the motions of the planets; while it is his pursuit to seek those which he does not yet know, with the unhesitating confidence that when once found they will never deceive him.

But if the actions of chemistry offer a far more wonderful subject of contemplation than those of the celestial system, so would they demand far more detail, from the infinitely greater variety of facts which they imply, as further, from the ignorance of the uninformed multitude respecting chemical agencies, and their inattention to those among which they are ever involved. Hence, while the appointed causes are unknown or not considered, He who ordained them is not contemplated; as even the great effects which they produce, or to which they tend, are not conjectured: while, very generally, this science is viewed as a mere art in the hands of men, a collection of technical details, and a power put into motion by ourselves. Hence would it be needful to show, at least, the extent of its power and agency, the range of its action through nature, that it might be known for what it truly is, the great vicegerent of the Creator on earth, and not on earth only, but throughout the entire universe. But, of all this, I have space for little, where a volume might well be occupied: it must suffice that I trace some slender sketches, which the informed chemist can fill up, and which even moderate reading will easily enlarge, under the present views, with the clue which I have thus given.

In doing this, it will be convenient to distinguish those chemical agencies which concern inanimate matter, and those which influence organization for the uses

of life under its two forms ; although these classes cannot be perfectly separated. And thence may a general view of the power of the Deity under this agent be derived, though we do not yet know in what manner it is exerted.

In commencing with the great universe, I must first offer a remark on an important conclusion of mathematics, namely, that as far as its laws have investigated the structure of the planetary system, it presents no indication of future change, or destruction. There is no apparent reason why it should not exist for ever as it now is ; while the same science has said that there is no reason why it should not have existed from eternity. If they who have thus argued have formed an erroneous conclusion, while they have thence been accused, whether justly or not, of atheistical designs, it is from confining their views to their own science, and being ignorant of the power and actions of Chemistry. The mechanical motions have been correctly assigned, but the matter has been assumed, and thence neglected. Mathematics have speculated on matter in the abstract, and forgotten the moving forces which belong to the chemical power. The great celestial motions may vary, and again return, to commence the same round of variations for ever, be they secular or periodical : but the motions under chemistry, in which the orbs are concerned, perform no such stated rounds. They are progressive ; bearing, to us, the aspect of irregularity and uncertainty : while they interfere, to our experience, and may interfere much more widely, with the mathematically eternal rest and order. Under purely mechanical views therefore, there may, or might be, a permanent solar system, and also a permanent universe. But as subject

to chemical laws, the universe is a changeable and changing one: and, as such, it is perishable, and might perish. I do not say that it might perish as matter, though of this we cannot know or reason: but be matter as eternal as it has been supposed by some philosophers, the solar system may terminate, and even the universe cease to be what it is. The forms, and the positions, and the magnitudes, might change, even though the total mass of motions should continue: while such changes would terminate the existence of any system as we now know it, or render it no longer competent to its present offices. And if this change, or destruction, can take place under the agency of Chemistry, so is it probable that for this, among other ends, it has been appointed.

Under this high view, if the laws of mechanics form the preserving power of the universe, so do those of chemistry constitute its changing one. It is thus the destroying force, in a limited sense, as it is also, in a similar manner, the creating one, under the direction of Him, the destroyer as He is the Creator. In this light indeed is chemistry easily viewed, under the smaller operations constantly proceeding in our earth, where it is the unappeasable destroyer both of the works of nature and of art: but it requires a far wider stretch of thought to consider it as exerting the same power over the immense bodies and systems of the wide universe. Yet this is a truth which we can scarcely question, little as we may witness; and if it be so, then has the Creator appointed the two great powers of Mechanics and Chemistry, the dynamics of each, as His agents: the former as the preserver of the mechanism which He has established, the latter as the creating, and also the

destroying power. It is a narrow view of chemistry which does not look thus loftily, which considers it only in its lesser details. It is His great agent for every change: it is more than the equal agent with the mechanics through which He arranged the order and movements of the celestial orbs. This is to take a just, if it be a lofty view of Chemistry; of the great, the ever-acting right hand of God, throughout the whole universe. Ever active, ever acting, ever performing His will, it is that power which must, daily and for ever, proceed from Him, and which will not permit us to think, as philosophy has so often wished, that when He had appointed the planetary, or the celestial system, He rested from His labours.

These are general inferences, which will be supported by what I shall now state respecting the history of the Earth; as it is thence also that I must draw certain deductions concerning the existence and power of chemistry in the other great bodies of the universe. And, in that history, the chief facts relate to, the mode and process of its creation: meaning, by that term, to refer to its visible existing condition. If the 5th chapter has already noticed this subject, it has not superseded what I must here say.

Here, the leading facts consist in the nature of the Earth's materials, and in the chemical actions which occur among them. Were it not for the sake of life, our globe might have been formed of abstract matter, if there be such a thing, or of one substance: while, complicated as it is, and alive with chemical actions, we cannot assign uses for the whole of its constitution, even under that design. A small portion only of its materials is applied directly to that end: and though we

add the uses which man derives from many more, a great deal still remains unexplained; above all, in those new compounds which chemistry is ever producing. Much indeed of this may be contingent on other and useful appointments, as our ignorance may also be in fault. But under any view the earth is far more extensively the produce of chemistry than of mechanics; as the course of its existence is also much more deeply regulated by the former than the latter.

Passing over the metaphysical question which regards the creation of matter, the obvious inquiry is, by what secondary powers the globe of the earth was shaped and consolidated. Mechanics cannot explain its chemical constitution, at least, nor has even its form been successfully explained on this ground, though it is the result of gravitation. This force could not have given it the present figure, had it been always the solid which the surface now is: it might have been polyedral, or irregular in many modes. And if some mathematicians have sought a solution in a long succession of transportations of the solid surface, the simple answer is, that the needful accumulation of such effects was impossible, under the revolutions which the earth has undergone. This hypothesis is moreover as untenable as clumsy; when a mobility of the solid surface, amounting to a virtual fluidity, and extending to an enormous depth, was necessary; since thus only could it have become the spheroid of rotation which it is. Even mathematics ought to admit that this globe was once fluid, since thus only are its own conditions answered. If such a proceeding is more consonant to the simplicity so general in creation, it is supported also by a large mass of evidence, while the other hypothesis can produce

none. And as that fluidity is the produce of chemistry, this becomes established as being, jointly with mechanics, the agent under creative power.

Although there is not evidence, there are reasons for believing that, prior to this state of fluidity, the matter of the earth was gaseous, constituting a sphere, of course, and being an integrant body in the solar system, as it now is. This inference, as I showed in the 5th chapter, is drawn from the examination of comets, which appearing to be purely gaseous in some cases, include, in others, nuclei variously proportioned to the investing gas, as if, in all, this was undergoing a gradual process of consolidation. The existence of gaseous spheres is thus, at any rate proved; which, for the general purposes of this chapter, is a vast and important fact: while, under a diminution of heat, such a sphere must become fluid, as the radiation of heat into space will explain the gradual and ultimate change.

The condensation of our earth from the state of a gas to that of a fluid is therefore the next chemical step in its creation; but though the preceding stage were discredited, enough remains to prove that what followed was the result of this power. And though it should be argued that the fluidity of the whole globe was not necessary to the assumption of its present figure, the agency of chemistry will equally be established. While this science is convinced that every solid can become a fluid, and every fluid a gas, through heat, it has proved these important facts in numerous cases, through its artificial fires; as my own experiments are responsible for the volatilization of silica. In volcanoes, we have the natural proof of the power of heat in liquifying rocks, their fluids being reconverted into those on

cooling. And geology easily proves that a large portion of the visible rocks of the earth, and probably a far greater one of the invisible, has been formed in this manner : still knowing that the stratified kinds are the joint product of chemistry and mechanical agency ; formed originally from the fragments of igneous and unstratified rocks, and, in latter periods of the earth, from both kinds, if, further, by animal agency, in the case of limestone. I may here also add, what has appeared elsewhere in this work, that the communications of volcanoes beneath the surface prove an extensive state of fluidity in the interior, while their effects further demonstrate the great depth of that condition.

Hence it is not unreasonably concluded, that such is the general or universal nature of the earth's interior at present, as it was, originally, the condition of the whole ; this fluid having gradually been consolidated at the surface, by radiation into those original rocks whence the first order of strata were afterwards produced by means of degradation and water. This inference is further confirmed by the nature of the Moon. Possessing no water, on our side at least, it also displays no marks of stratified rocks. The whole surface is of a volcanic or igneous character, the probable counterpart of what the Earth became by similarly cooling, and continued to be before the commencement of stratification. If this is a restatement of things noticed elsewhere in this work, so, may I again add, is it the power of chemistry which has so often renewed the forms of our globe, as to that agency are entrusted the changes which it is yet destined to undergo. Of some of its further actions in rendering the earth what we know it, I shall inquire hereafter.

But I must now interpose a remark. This theory has been accused of an atheistical tendency; and, apparently, because it has recently been renewed, not produced, by that high mathematician who has so often incurred this charge. Its fate has been singular. That it bears a vague resemblance to the system of Epicurus, is apparent: but that system is nothing, since it assigns no causes, and indicates no process, from its ignorance of chemistry. But it was adopted by Burnet, and Whiston, and others, whom nobody will accuse of the same error: though, with them, being little better than before, since they also were deficient in the requisite chemical knowledge. Whoever shall now accuse it of atheism, must commence by showing that the chemical power is a voluntary agent, independent of the Deity: and to this I need now make no answer. It is His agent: if it creates slowly, it is, that to our conceptions of time, every analogous proceeding of the Creator is slow, as I have formerly had occasion to remark. The seed wearies our patience in its progress to the centenary oak: it is a tedious interval between the inappreciable germ and the man perfect for all his ends. Islands, perhaps continents, are forming daily, through operations so slow that centuries scarcely mark their progress. The earth is not yet created: it is daily in the act of creation. And the moral world presents the same picture. All is slow,—I must repeat what I have more than once urged,—as if time were indeed nothing to the Deity. But that the production of the solid earth was a tedious process, does not render it the less His work. And wherefore was it necessary for Him to produce a habitable world in an instant? Commanding eternity, not time, there is no necessity. But we are misled by our own

works, and by our own necessities : by our own self-valuation: making man, in this, and in far more than this, the standard for God.

Under this view of the creation of the earth, the whole forms one beautifully consistent and progressive system beneath a general design, analogous to all else that we know of the Creator's works. His great agents, chemistry and mechanics, execute the plan, in consistence with what we can prove of their powers and actions : while we know that He works by means, and do not know of any others by which He does work on matter independent of Life : as, even under the guidance of Life, it is Chemistry which is His agent in the construction of organized forms.

Thus is the solid and insensible earth, as I have already said, alive with motion : teeming with life, the life of chemistry. It was not created as a terminated or complete work, to be the same body, and perform the same offices, as long as it should exist. Much less was it once finished, to be then abandoned or left to itself. It has never yet been finished, and we know not that it ever will be ; though, on other grounds, we can believe that it may ultimately be destroyed, or rendered unfit for its present uses. At every instant, and for ever, under the power and the action of the Deity through His great agent, Chemistry, it is ever active and ever changing, ever under acts of creation ; while its changes, as I have formerly shown, tend to a progressive improvement, though under a perpetual vacillation from worse to better and from better to worse again. And here surely, where His power, His Life is, does He abide. For ever regulating, by His immediate presence and will, the mechanics of the earth as a portion of the

celestial system, so must He regulate its chemistry : and if it can be inferred that this chemistry pervades equally every globe of the wide universe, then is that power indeed worthy of the elevated station which I have here assigned it, as His vicegerent throughout creation ; jointly with mechanics, constituting the two great agents to perform His biddings throughout the infinitude of living space. But it is a greater and a more splendid power in His hand : universal as centrifugal motion and gravitation, while its actions are far more multifarious and complicated. The machinery which these might have produced, and which they might solely have regulated, could have been, comparatively, but a dead, and, to our views, a purposeless one : chemistry inspires it with a living soul, and becomes also the instrument, in myriads of beings, of that Life without which we can see no purpose in the celestial universe.

From these general views of the operation of chemistry in the earth, I must now turn to inquire how far we can infer its wider, or its universal agency throughout that universe of spheres. Of all these, the Moon is the most intelligible to us : since our telescopes enable us to decypher its surface to a considerable degree of minuteness. It is a rocky and mountainous globe, under two leading divisions of form, resembling the granite ridges of the earth and the craters of our volcanoes, even in their details. If the altitudes of those mountains had formerly been overrated, they are still lofty and numerous : while the craters far exceed our own in magnitude and number ; being crowded, and even reduplicated, over nearly its whole surface, and very remarkably near that spot called Tycho. And

the proof of their nature is perfect, since Helicon, and, I think, Aristarchus also, have been seen to burn in our own times. Hence this globe admits of the same reasoning as the earth, as its origin and constitution are concerned. It is a great chemical laboratory, which has undergone, and is probably still undergoing, extensive changes. The possession of some atmosphere, at least, draws the resemblance still closer : and since we can see but one half of its surface, we must not decide that it does not contain water, and thus, possibly, be also the seat of life.

Respecting the Sun, we are not confined to the emission of light and heat as proofs of its chemical nature and action. The changeable spots on its surface indicate the same thing : while their frequent magnitudes and changes prove that a series of immense chemical operations is continually proceeding in this most important orb.

Among the planetary spheres, our command over Mercury is narrowly restricted, from obvious causes : but if it possesses an atmosphere, as has been thought, the same conclusion follows, as we might safely infer a chemical constitution on all other points. The case of Venus is much more decisive ; since it contains mountains which must have been chemical productions, like our own, implying actions involving the whole of its globe. If the red colour of Mars proceeds from an atmosphere, as is supposed, and if also the marks at its poles be snow, the same inference follows. In Jupiter, the changes of the belts lead to the same conclusion as the spots on the sun : but of Saturn and Uranus we can only reason from general analogy, since they lie beyond the bounds of accurate observation.

Obscure as the theory of the four small associated planets may yet be, it seems admitted that they are portions, or fragments, of a prior single one. The question here is, whether this was the result of chemical or mechanical force, while it has always been referred to the latter. But they who refer it to collision with a comet, leave much to explain: departing also from their fundamental and valued principle, the mechanically eternal order of the system, in admitting disturbing forces to which no limits can be assigned. It is for mathematicians to answer: but if there is another power in the universe, known to act in the requisite manner, if not in the requisite degree, it seems entitled to at least an equal consideration. Is it impossible that chemical power could explode even a planet; or cannot we conceive a force of expansion capable of overcoming any given pressure? If this solution should be the true one, this is the greatest example we have yet seen of the changing or destroying power of chemistry in the universe: while, as far as the planets are concerned, it is the last point to which inference can conduct us through our own system, respecting the agency of this source of motion.

On merely physical grounds, this may justly be deemed a hypothetical speculation; but under other views it is not an unreasonable solution. The power of chemistry is immense and universal: it may be a far greater agent than we know it to be in our own globe, both for destruction and renovation: in the Creator's hands, illimitable. We know not how heat is managed, beyond the very little that we see. In the great bodies of the universe, it acts, and has acted, most extensively, and in so many ways unintelligible to us, that we cannot

assign any mode of limitation or any bounds to its effects. And should the present view be just, the object I wish will be attained, since it will convey the highest possible conceptions of the powers of this great agent, and of the great and splendid ends to which the Creator has applied it in the government of the universe.

Having already alluded to the probable power of Chemistry in changing the form of a planetary system, in opposition to those mechanical forces which tend to preserve it, we now see more clearly how it might really act in changing the places and weights of such a set of bodies, still permitting a permanently equivalent balance for the whole: as we have already seen, in the case of the earth, how the quality of a planet may be changed while all else is preserved. It may be true, as La Place says, that such changes cannot happen from anything which we now see: but that is true to the mathematician only, who limits his views to mechanics: since we do see an efficient power. The operations of Chemistry in the earth are a sufficient warranty for this possibility: the powers which have so often changed the distribution of the fluid and solid parts still exist within it: and no one can pretend to limit their future actions. Thus might the mode of the diurnal rotation be changed, in a very obvious manner, as it may already often have been; while even greater alterations are easily conceived, and those extending throughout the whole system.

If the meteorolites should ever be proved to be fragments of the presumed planet whence the four smaller ones are thought to be derived, it is easy to see how they bear on the present views: but whatever origin they may have, not being terrestrial, they show that Chemis-

try is at work in some distant parts of our system, or that this great power pervades it everywhere.

The comets are the last portion of the solar machine requiring notice : and, here, even the superior influence of chemistry to mechanics is seen. If, as is thought, they shine through a light of their own, they are as much chemical bodies as the sun : they are such as gaseous bodies, or as fluid, or solid ones, surrounded by atmospheres : their trains are equally among the most splendid and wonderful effects of chemistry. Whatever be their use or destiny, we must consider them as enormous laboratories, carrying on immense chemical operations, if for purposes yet unknown.

If it remains to extend the probable range of Chemistry beyond our own insignificant system into the great universe, the facts are few, if there be indeed more than two of any value ; so that we must depend chiefly on the argument from analogy. Every star is a sun, and therefore a chemical body emitting light and heat ; since whatever else these may be, we cannot at present dissociate them from chemistry. But there are coloured stars : and thence perhaps a new argument may be derived. If light is everywhere the same thing, the colour of a star ought to be the result of refractive dispersion, and it should possess an atmosphere, of whatever nature a solar atmosphere may be. Again, stars have disappeared, as they have appeared for the first time ; of whatever kind those spheres may have been. If this be the collection, or creation, or the dispersion of an orb, the powers effecting this must be those of chemistry : if it is but the imparting and the deprivation of light, the argument remains the same.

These proofs ought to suffice, as should the inference from analogy alone. Of the planets of those suns we know nothing : but presuming on their unquestionable existence, the same conclusion applies ; namely, the universal existence and agency of chemistry. And not only in every solid orb throughout space, but through space itself : being universal therefore in a much stronger sense than mechanical power, since this has its places and its bounds. Light pervades all space : so does heat : and each acts wherever it meets a subject to act on.

Such is the universal spirit of chemistry, existing everywhere, everywhere acting or ready to act, occupying every atom of every orb, pervading empty space itself, if such a thing there be, and so filling it, that we cannot conceive even an incommensurable point where it is not. There is then no vacancy in the universe, no place where the agents of the Creator are not, where His power is not present and active, no point without its life. And if there is not one where the physical agents by which He works are not ever doing His biddings, not one where His energy is not for ever displayed, then is there no point in all the immensity of infinitude where He is not for ever present. This is the living universe : and did I then say wrong when I said that it was in chemistry, rather than in the much more noticed facts of astronomy, we should seek the universal presence and power of God.

In proceeding to the more obvious actions of chemistry in the earth, I must premise a remark which especially concerns its races. Certain points of rest, or of a limited perfection, have been successively reached by our globe already, as periods of subversion, or de-

struction, have succeeded these, with subsequent renovations, repeating the same career. The life of the earth, under any one period, has borne a vague analogy to animal life : and such probably have been the lives or periods of all the planets, as, probably, in all, there will occur future and similar changes. If the past agent has been chemistry, so, we cannot doubt, will it be that through which all the living races will be extirpated. Of a great day of judgment we are forewarned, as we believe in a renovated earth : and to this power we must look, under both. We are threatened with fire : and the works of this agent have already been the works of fire. The facts confirm the promises : as the belief in a termination through fire pervades every system of mythology not less than our own religion.

Pursuing now the chemistry of the earth where almost alone we can study this power, I shall commence with the organized beings ; reserving to the last the little I can afford to say on that of its inanimate matters. I have already remarked that every system in the universe, or the universe of orbs itself, might have existed under mechanical laws alone. The celestial machinery would have been equally perfect, and apparently more durable. But to what ends ? With light, though that were its sole chemical property, it would have been a still more unreasonable creation ; since here is a great contrivance for no intelligible purpose. Again, finding, in one globe, an atmosphere and water, and inferring the same of others, we multiply the inutilities in extending the chemical contrivances : doing this still more as we continue the same inferences respecting all the chemistry of our own. But finding that the only globe which we do know contains organized machines

tenanted by life, that these are constructed by chemistry, and that the substances and actions under it are very widely necessary to Life, while useless to the merely celestial mechanism, we must conclude that this is the great or sole purpose of chemistry, that it was appointed for the sake of living, and, ultimately, of sentient beings. This is immediately obvious as to light, and perhaps heat: it is equally so as to water and air: it is the same, if less strikingly, as to far more than I need detail: and even the great chemical actions within our globe tend to the same general purposes.

Thence I may derive an argument of great weight for the plurality of inhabited worlds. It is much closer drawn than that which astronomy furnishes; since that science can, in reality, but draw this inference from moral reasoning, if it has not always perceived this. On our globe, chemistry is purposeless, except for the sake of Life. It pervades the whole universe, and is, in contrivance, as in extent and variety of action, a much more remarkable power than that of mechanics. Such a power could not have been appointed thus widely, or universally, but for a great purpose, which can scarcely be aught else than the universality of living beings. And these also ought not, essentially, to differ from the beings of our own globe, since they are related to the same actions, if not so certainly to the same substances. The reader will perceive that this is an extension of the argument on the same subject which may be derived from the universality of light.

To proceed to the facts, and commencing with animals, the object was to produce a machine capable of being moved by life; which, for reasons elsewhere shown, was to be terminable and reproducible, while it was also

to commence in what may be termed nothing, and to attain its size and form by certain degrees. This demanded more than one form of matter, with a species of motion different from that which rules the celestial bodies: and these are the chemical elements and the chemical motions. As I have shown on other occasions, if we assume a single life, or vital unknown principle, it is attached to some atom, or quantity, of some matter, we know not well what, as we cannot conjecture how. That vital principle possesses a command over the necessary chemical substances and actions, and the machine is gradually erected. This structure produces other such quantities of the same matter, to which the Creator communicates other vital principles, proceeding in the same manner; while the original machine becomes inefficient, so that its life disappears, and it becomes disintegrated into those modes of elementary or subelementary matter whence it was first constructed.

If we know not what Life is, neither do we know how it is communicated by the Deity: but from all that we can see, or infer, He has reserved it in his own immediate hands, committing to His great agent, chemistry, the execution of the machine, yet under the direction of the same power, Life, as that ruler of chemistry which I have pointed out on other occasions. As little do we know how He recalls or removes the principle of life, or in what manner it is disposed of: while it is recalled, apparently, in consequence of some failure in the machinery which it produced: the same agent returning the elements into some common stock, whence they again proceed in the same round. This is life and death. Let the physiological materialist continue to

assert that, as disorganization is death, so are the powers of life the results of organization : he must yet explain what that life is before the organization is completed, or even commenced : while it is no proof of his logic or sagacity to have overlooked a question as unanswerable as it is simple.

But the power exerted by life constitutes a mystery even greater than that of its existence or communication : since it arranges matter into forms which we can explain neither through mechanics nor chemistry. The first give us nothing but spheres, under the principle of gravitation : the only defined forms produced by chemistry are crystals. But life constructs the most complex and varied machineries : repeatedly also producing additions, or parts, as long as those exist. What power is this, which belongs to neither of those two great ones, yet effects what they cannot, while it controls them both ? The materialist should answer, else are all his systems a mere nullity. Theology indeed cannot give the solution which philosophy demands : it cannot define that third power which, with mechanics and chemistry, has been appointed for the arrangements of the universe. But it will be ready to believe that there is such a third agent, under the Creator's will, whenever its separate nature shall be shown : while, in the mean time, it has this advantage, that it can substitute something,—that it knows of a competent power, and that power, God.

This unknown power is not limited to the construction of one form of machinery : in animals and plants, the forms are hundreds and thousands ; and each of these produces points or parts which, under new lives, repeat the same exact machine for ever. This is still

more unintelligible: it highly enlarges our views of the power which performs those duties: while, if it be a secondary agent, the utmost mysteries of chemistry are as nothing in the comparison. Should any one assert that chemistry itself is competent to all this, then is our ignorance of this science so great that we must renounce all pretensions to comprehend it; nay, the very term itself.

It is but a small difficulty compared to this, that one division of life in the organized beings should direct chemistry to the production of one general species of compound matter, and the other to a different one: that vegetable machinery is constructed out of different materials from that of animals. Yet even in this we must see that there is an agent beyond chemistry, gifted with choice, as well as design, possessed of knowledge as well as of power. Can the Creator have deputed such things to any secondary and not intellectual agent? This is inconceivable. If any one shall answer that there are distinct species in Life, this is not the answer of a materialist at least. But, in truth, materialism has ever dealt in generalities, whether from ignorance of physics or incapacity for analysis, or from knowing that they form the best security against detection. But if the intentions, as intentions there must somewhere be, are said to exist in the Lives, how will metaphysics explain? If they cannot, then, again, are the intentions those of the Creator, and He works here by His direct will; omnipresent, and ever-acting. If I have spoken of this elsewhere, using the term pattern, and the phrase, commanded by the Creator, it was necessary to examine it here, in inquiring of chemical power, as the mason in this case, under the direction of the architect.

Proceeding to that which is more purely chemical, the vegetable lives select, out of the surrounding materials, carbon and hydrogen in the largest proportions, with far smaller ones of oxygen and azote: reuniting what we at present suppose to be elements, into the peculiar substances whence their machines are constructed. The animal lives, on the other hand, separate and combine, chiefly, hydrogen and azote, with carbon and oxygen: each division, and the latter more remarkably, adding some rarer matters, required for particular purposes. I need not however detail these various substances: all that was required in this work will be found elsewhere.

But as chemists do not contemplate their science under the present bearings, and as it has been neglected by the writers on natural theology, while the multitude only know of it as an art, I must extend some of the foregone remarks, since thus only is the purpose of this work attained. I have often said, that the best mode of turning our attention to the efforts of Divine power, is to put the production of an object or effect in the shape of a problem to be solved, supposing the means unprovided. In the present case, the intention was to construct a machine capable of moving and acting, in a world which we must now conceive to have been a structure of mere matter under motion. Man executes something similar, by building up or shaping out, through mechanical power, existing masses which I may here consider as abstract matter: while, excluding chemistry, his means here end. He cannot so construct his machines that they shall preserve themselves in repair, be reconverted into equal and similar ones after being disintegrated, or produce others of the same kind. The

problem is not to be solved by mechanics ; and the Creator has therefore established other powers for its solution. If the work was still to be executed from existing matter, He has prepared many kinds, and to those He has communicated various powers of motion and tendencies to union. It was necessary, for the sake of reproduction, that He should build up His machines from minute or ultimate parts ; as this was also required, that they might be capable of disintegration, for future and successive uses of the same kind. His chemistry performs both offices ; though directed, in the first case, by a third great power, that of designing, under Life : and thus the entire problem is solved, and solved for ever. Or, in more detail, He has provided certain elements, such as oxygen, hydrogen, carbon, and others, and thrown them into a common stock, on which His chemical agent draws under the direction of the third power : returning them to that stock when the machine has served its purposes, or has become useless under the rules appointed for its duration. And this round will continue until He shall think fit to terminate it by withdrawing His lives : since we can no more conceive an end of the chemistry than of the mechanics of the universe.

I need scarcely then now urge, that whatever be the power of chemistry, it operates only on dead matter, through attractions and repulsions : terms which, if for ever treated as if they were causes, are but symbolical expressions of that which is unknown. In the present case, it destroys the machine with the same indifference as it wrought in the production. There is a power beyond chemistry which directs it to build, even as it

directs the forms : and this is Will, which, in constructing, is Intention, in designing for ends is Intelligence ; which is Mind, and can ultimately be no Mind but that of the Creator. Without this, not even could the mere matters of these machines be formed from the elements ; since these have never yet been produced by pure chemistry, which, on the contrary, destroys them when the power of mind is withdrawn. But it is worse than careless to speak of the chemistry of life or growth as if it differed from that of death or destruction ; since it is convertible to one of the supports of a materialism, by tending to exclude the directing power of life. As I formerly had occasion to say, there is only one chemistry : but the living machine is always losing that balance of its elements through which the organization is maintained in an efficient state, because it is performing motions unknown in the same dead matter. This it must replace, or the organization is ruined and the life is withdrawn. It here performs what it did in constructing the machine, and thus only does the chemistry of life differ from that of death. Nor is there any difficulty in admitting that life should rule chemical action, as far as analogy at least can remove this ; since it produces, and under will, the corpuscular attraction of the muscular fibre.

I cannot here take room for the details of the endless compounds under life, few as the elements appear to be. Yet if I name the vegetable odours alone, it is utterly inconceivable how they should be so numerous and various ; while they must be distinct substances, or they could not be distinguished by the nerves of smelling. It is not less marvellous that the power of life should

direct all these combinations, and, under each separate machinery, direct them for ever. The odour of a Rose has never varied since roses were created.

Considering general views as of more moment than details, for the present purpose, I may ask the reader to picture to himself, if he can, all the motions and combinations of chemistry, as if he could see the elements themselves, and follow all their movements with his eye and his hand. Like the bodies of the great universe, those of the celestial spheres are the most striking to us, from the magnitude of the one and the extent and rapidity of the other : yet they would scarcely be objects of attention could we see the materials and their motions in the chemical universe, nay, possibly, in a single plant or animal. The imagination must be called on to do what has been refused to the eye. Could we now see the celestial orbs arrange themselves in the form of a tree or an eagle, we should be filled with astonishment : yet such wonders are for ever occurring around us, though we see them not : visible to the Universal Perfection by which they are commanded, and possibly, in some future state of being, to be rendered sensible to ourselves.

I cannot afford to say much on that portion of the chemistry of the earth itself which is external to the organized bodies, though appointed for their support ; while the principal facts also have necessarily appeared in former chapters. If hypotheses have been proposed respecting the production of water and of the atmosphere, from a globe of mixed elements, it is sufficient to say that this is at least within the power of chemistry, though we cannot assign the details : knowing that every element can exist in a solid state, and be rendered

aëriiform by heat. Suffice it for the present purpose, that these great bodies are chemically constituted, and moved by chemical powers : executing numerous offices, formerly indicated, and, as I have just said, serving to produce organization for the sake of life.

In this latter case, I have elsewhere shown that there is a circle between the two chemistries, of the animal and vegetable machineries, involved within the great external circle by which these are supported : the disintegration of the one producing materials for the other, on each part. This view however is general as it is popular : it is not chemically accurate : since the proportions of the united elements differ in these two departments of life. It is more just therefore to consider all the materials arising from the destruction of each class, as thrown into a common stock or great outer circle, whence the inner circle of life is to be supplied with materials. But if the water and the atmosphere constitute the more conspicuous part of the great circle of supply, they do not form the whole : since the solid earth shares in it, affording, to plants at least, some portion of their own and the animal materials, there stored up after decomposition, together with some substances not known to exist in the atmosphere at least, with some scarcely found in water. Hence does the vegetable ruler of chemistry collect what it wants, as it afterwards gives up its materials to animals, unless as they perish unconsumed : and to this do animals return what they had received, for the use of vegetables, again to renew the same round. Whether there may not be a shorter circle for animals, through which they collect their materials immediately from the general store, I have elsewhere inquired, and can throw no more light on that obscure question.

If the chemical power is thus universal, as we have seen it to be, if it is also operose and multifarious, yet to a far greater degree than I can here undertake to show, if it is by means of this power that Life is rendered efficient, and if, further, we can discover no other purpose for this great agent, then must the important conclusion follow, that the life for which the Creator has thus wrought and cared must be of high value in His eyes: even did we think fit to doubt that the great celestial machine, with all its myriads of orbs, was created for that end and that alone. Justly then may we say, if in another sense than that of the original, God is not the God of the dead, but the God of the living.

I must select and condense from what remains of the proceedings of chemistry in the Earth, while the chief end of this chapter ought now also to be attained; and as much that might here have been said has found places as needful, in other parts of this work. It is for the reader to recall these, and to view them in the same light; without which he will not fully apprehend, as he might scarcely believe in, the universality and energy of that great power which embraces every substance, and acts for ever and in all things.

Be the globe of the earth, or not, that chemical production which I have attempted to prove it, to this power at least is it chiefly indebted for the form and distribution of its surface, as it is for the whole of its materials. It was chemistry which separated the great elements of the land and the water, which formed the latter as the wonderful substance which it is: it was chemistry which made the not less wonderful atmosphere, and, jointly with mechanics, it is the power by which that is main-

tained and governed. Again, it was chemistry which elevated the mountains and hollowed a bed for the ocean, thus distributing all the physical geography of the earth. Whatever mechanical power has here effected, it has been rather for destruction than the reverse: while, without the aid of chemistry, it could have acted but little on the solid land. If islands are ever rising in the waters to extend the place of man on the earth, it is to chemistry that the Creator has committed their production, be their constitutions what they may. Often too is His agent here a living chemist; chemists in myriads, blindly performing His will, while conducting the little circle of their own narrow lives, unconscious of the future Apennines, of the extended continents, which will hereafter tell of their labours. And where these duties find their necessary termination, again He calls for the volcano; while, once more, His chemistry, exerting its higher and more conspicuous powers, completes the work. This was the ever-obedient servant also which wrought out the plants of past ages from the invisible elements of those distant days, which turned them into an inorganic mass, which made that mass coal, and, lastly, which brought that valuable substance within the reach of man. Let our springs rise and our rivers flow, through mechanical power—it is here but the handmaid of chemistry; for by this were the channels that conduct them produced or founded. The great chains which, like the Andes and the Caucasus, ridge the surface of the earth, every mountain that must rise throughout the globe before gravity can aid the descending waters in furrowing their way to the sea that they may return again, owe their birth, as I have just said, to chemistry; as it is the same power which

must precede mechanical force, before those mountains can themselves reach the hollows of the land and the waters, to level valleys, fill lakes, extend continents, and form islands, and thus to continue the work which it originally commenced.

Thus has chemistry been that mechanician of the earth's surface which I have just suggested : an unexpected duty to him who is ignorant of its history, and unthought of also by the purely mechanical philosopher of former days ; as it is, to the small critic of Creation who so often asks, why He did not shape the mountains at once by mechanic power, and to the narrow theologian who, too often confounding the language of metaphor with fact, knows not that the Hand which measured and weighed was not that of the mechanic, but that great right hand through which the Creator has executed His will on earth, as, for this end, did He appoint it.

On our globe too, the most difficult portion of the great circle of the waters from the ocean to the ocean again, is executed by chemistry alone : not merely disdaining mechanical aid, but triumphing over its boasted powers : while we can now smile at the philosophy which so long attempted to explain this, under that joint load of antiquity and ignorance which I have so lately noticed. If it carries the weight of waters far aloft into the regions of the thin and light air, executing that which, did we not see it and know it, would be incredible, it is even into those regions where it has raised the mountain to arrest their progress and return them to the earth before they reach the place where they came : even thus remotely, labouring for life. Here too does chemistry labour for this great end in another manner :

since it prepares the soil from the rocks which it at first formed, leaving it to mechanical power merely to distribute that place for vegetable existences which it has produced. And here is it, hourly and for ever at work : ever renovating what is for ever removed or consumed : removed by those mechanical forces which it has appointed to check or oppose in this case, as, in others, to aid or precede; consumed, through its power, by those living machines which again, under its guidance, return all to the great store whence it was derived. And while it produces the place for the plant, and brings the water for its food, it so forms that place as to detain this food for use, for ever repairing or restoring it, as it is injured or removed. If the air and the water are the great store for the food of plants, so are the rocks prepared to supply the materials of their habitations : but it is Chemistry which formed them all, and brings them all into use : brings them to those existences which cannot seek them, and, in doing this, is equally the parent and the nursing-mother of all the animal races.

This is a magnificent circle,—I have said it before, and not less simple than it is beautiful; as, with little aid from mechanics, it is the work of chemistry. That very element in the water which aids to feed the plant, destroys the rock to form its habitation : the power which elevated the rock as a perpetual store for mechanical force to distribute, raises the water also to destroy that rock, which, in descending, is to convey to the plant both its food and its habitation. It is truly magnificent and beautiful : but if overlooked, by some from its familiarity, and by others from want of knowledge or reflection, so does its very simplicity, the source of its peculiar beauty, defeat, to common minds, the impression which

it ought to produce. And if there is a reader who thinks that all this was necessary, or unavoidable—a contingency, not a contrivance, let him learn to know the Creator better, or in vain will the great book of nature be held up before his eyes. Not one of all those things was necessary: all has been appointed, arranged, intended: all is under the laws of chemistry, and in those laws there is no chance. Every purpose was designed, and every one is attained, as surely and as consistently as are the motions of the heavenly bodies: but it requires other knowledge, and another course of thought, to trace the conduct of this power; while the conspicuity of the former, and the long exclusive pursuits of mechanical science, have diverted attention from this less visible agent and its actions. We admire and we wonder at the great celestial machinery: we praise our own machines when they perform their duties well: and shall we not admire and wonder at the machinery of chemistry, though the parts and the movements are too minute for our sight?

It cannot be necessary to proceed. Beyond this, the reader who chances not yet to know what chemistry performs in the earth, what it does in the hands of art, as in nature, will find all that he may desire, in the innumerable works on this subject; this unexhausted, and perhaps inexhaustible science. My object did not extend thus far: but he who reads further, must take care not to lose himself in the multiplicity of small details, and forget that it is what I have so often termed it, one of the great and mysterious powers established by the Creator to rule the universe under them: His great vicegerent for Life, pervading the celestial orbs through all space, pervading all space itself. Under

its powers, all matter is alive with motion, an unceasing mass of myriads of motions: every atom which constitutes the universe, ever moving or seeking to move. Is there no rest under mechanical power? there is no rest under chemistry: there is no rest in the universe. It is a universe of motion, existing but under motion. Withdraw but the one power of Chemistry, let Him withhold that Hand, and Life is no more. The rest of Chemistry is the rest of death. But it is the rest of the Creator's hand: for His hand and His spirit are the hand and the spirit of Chemistry.

CHAPTER XXXVIII.

ON THE MECHANICAL PROPERTIES OF MATTER.

THROUGHOUT the greater part of this work, it has been sufficiently easy to select subjects evidential of the attributes of the Deity, of such a nature as to be intelligible to every reader, even without the very limited attempts at instruction to which such a book must be confined. Yet it would have been unjust to its purposes, to have omitted such evidences as demanded greater knowledge from Him; as being of a more abstruse nature, and, at the same time, but imperfectly understood by science itself. Thus have the reader's difficulties been gradually increasing, under the inquiries that relate to the great bodies which comprise matter and motion, and those that refer to mere action; to the exertion of some secondary powers under the Prime Power. Nor need I say the "reader," only: when the writer is perpetually checked by the imperfections of science on those points; compelled to stop short, because the subject is incapable of explanation, or by the difficulty of placing in a popular and definite view, that which philosophy itself knows only in generalities, or under a conventional or symbolical language, which is often also a hypotheticalal one. Thus did it become expedient, in the hopes of being more widely intelligible, to select what was best understood or most

easily explained, together with that which best admitted the exclusion of scientific, and the substitution of popular phraseology. Still, a task remains for both; in this attempt to point out some of the most interesting facts under the mechanical properties of matter; those properties which have been allotted to it for many important purposes. In the provisions themselves, we see those examples of the Power of the Deity which are always most striking when the secondary causes are incomprehensible; and in the ends attained, we perceive Wisdom, whenever we can comprehend the connexion, with Beneficence in the purposes served. And whatever of obscure or unsatisfactory there may be, the reader's thoughts will still have been turned to certain agents and acts of the Deity which he may never before have considered: with the beneficial effect of expanding his views of the Divine agency, and, in thus causing him to see the hand of God where he never had conjectured its presence, to make him feel the universal range of that Presence and Power.

If it is chiefly in conformity to the usual language of science, that I have used the phrase "mechanical properties of matter" to express the facts here to be pointed out, it was also necessary to distinguish in some manner that which does not appertain to Chemistry, or rather, cannot be proved to belong to this power. Yet is this, in many cases, little better than a conventional division: as I cannot also but view this phraseology, and the theory which it implies, as a relic of that ancient philosophy, once the only philosophy known, on which I have already made many remarks. But it is impossible, at present, to know how to act: entangled as we are between that new science, Chemistry, of the

nature, extent, and limitations of which we really know nothing, and the more ancient mathematical or mechanical science, the language of which is hypothetical, or at least symbolical and abstract, not that of known facts.

It is on the attraction of cohesion, under different modes or forms, that all the properties of matter which I here propose to notice, must ultimately depend ; and the difficulty therefore is fundamental. The mechanical philosophy naturally ranked cohesion with gravitation, under the general term attraction ; and thus has it been considered a mechanical property of matter ; while theories, often of great ingenuity, leading to valuable calculations and results, have been applied to the solution of many cases connected with it. But here Chemistry interferes, with its own minute and peculiar attractions, productive also of cohesion : as it does, still further, by claiming to itself, that power of repulsion under the action of heat, which is the balance of the attraction : not only in its own specific cases of combinations, but in the changeable conditions of simple bodies.

Under this uncertainty and confusion, arising from our ignorance of the minuter forms or modes of matter, and of the actions through which those are influenced, there seems no resource but to submit to usage : to adopt the mechanical philosophy in speaking of the forms of matter here to be noticed, and to reject entirely the consideration of Chemistry. It is, however, the substitution of convenience for truth : as the consequences of our ignorance of the truth will also appear, in every stage of our progress through this difficult subject. Yet the facts selected for the purpose of this

work, will not fail to possess the same kind of interest which has already occurred in treating of what Science does not yet understand : and if I have thus noticed its ignorance, it is, that I might caution the reader against receiving the language of hypothesis as the description of facts, and also provide a reason for the obscurities which will appear in this sketch. Further than this, the present work is, in no case, called on to investigate science, either in its truths or its obscurities : as, in this especial one, its object is to trace useful effects to their nearest assignable causes, and, when it is stopped in its further pursuit of those, to rest in the Will of the First Cause.

If the first great property of matter, demanding attention, is gravitation, it is sufficient that I now notice that which relates to the terrestrial gravitation at the surface of the earth, as the cause of the weights or specific gravities of bodies : whatever was here needed respecting that of the great celestial masses, has found its place elsewhere. The prime relation, here, is to the Earth, as the centre of attraction ; whatever others there may be, appertaining to the bodies themselves. The other properties of matter may be viewed as internal, or independent of proper gravitation ; and become necessarily ranked under the attraction of cohesion ; however that be modified by those mysterious powers of repulsion, of which we feel that we know less than even in the cases of pure chemistry, so singular are the effects produced by that, which, on the mechanical hypothesis, can be nothing but a combination of attractions and repulsions in the supposed ultimate parts of matter. Those properties are, tenacity, or strength, under various forms, hardness and its re-

verse, brittleness, toughness, stiffness, flexibility, and elasticity: as, among these simpler properties also, many modifications and combinations exist. From the great mass of facts which rank under these, I must content myself with selecting a few that most bear on my object; which is, to point out the wisdom and power displayed in the contrivances, together with the final causes, or the useful purposes which are thus effected.

Before entering on any of the details respecting gravitation, I must notice the wide utility and diversity of the effects which are produced by this simple law. It has been often observed, that this is the perfection of wisdom: it is the true simplicity and beauty of Creation. The same power which is the bond and basis of all the celestial mechanisms, is also the cause of form and solidity in our own globe. Through that power the ocean finds its place, and the atmosphere exerts its great and useful pressure, as it is thus the permanent investment of all things. By the same power it is, that the sea fluctuates, both in its tides and its waves, that the rains descend and the rivers flow; that the soil is renovated, and that new lands are formed, to extend the surface of the useful earth. In works of art, it is the power to resist external forces, and it is the similar cause of stability to animals, if, more partially, to vegetables also. Through gravitation, man acquires the command of force, for endless uses: and thus are even the seeds of plants disposed for propagation. And if, as I have elsewhere attempted to prove, this is not an inherent property of matter, but the perpetual action of the Deity, then is His hand ever at work, on the earth as in the great universe, in the most minute, as in the

most important things : acting everywhere, at all times, in everything, throughout all Creation.

The gravitation of a body is proportioned to its quantity of matter : or, on the earth, its weight, or specific gravity, is the measure of the matter which it contains. This sounds like a philosophical fact of some importance ; and yet it is merely an identical proposition, as its basis is an assumption. Of matter, abstractedly, we are utterly ignorant : under this view, it is, simply, gravitation : and the quantity of gravitation is therefore the quantity of gravitation. But the substitution of terms is convenient. It must therefore pass : yet it must not be allowed to mislead, by pretending to explain that, of which it knows nothing. Magnetism is a source of attraction, as gravitation is : and who is there to maintain, that modes of matter, independent of the quantity of abstract matter, may not possess distinct powers of gravitation ? The attractions of Jupiter and Saturn towards the Sun, are much inferior to that of the Earth, comparing their relative magnitudes. The answer is, that their densities are less. It is a convenient answer ; but it involves enormous difficulties. But I need not dwell on these fundamental difficulties, which I was, nevertheless, bound to notice : there are many more remaining, under questions of detail. And in stating those, let me repeat what I have often said, that this is the very business of Natural Theology ; as the object is not to show the imperfections of science. They are the very difficulties, or “ wonders ” of Creation which indicate Almighty power and resource. Therefore must they be displayed, not suppressed : while, least of all, can I suffer hypotheses to pass without examination, whatever the authority of those may be ; since this is to

admit or adopt fiction, with the effect, if not the purpose of turning the attention from the First Cause.

If now we take the relative weights, or gravitations, of two bodies, such as platina and silver, for example, we find, that under an equal bulk, the former weighs twice as much as the latter. According to the usual hypothesis, it contains double the quantity of matter in the same space, or is of double the density. This is easily said, as it also suit the hypothesis: but it leaves the mystery unsolved. To all experience, silver and platina are equally continuous: and if matter is one thing, how can that fill a greater space and also a less one? while, in resorting to pores, philosophy is inferring from a vulgar fact, which is without any resemblance or analogy, of which it knows. These are the resources of the corpuscularian hypothesis: which, having adopted a fiction, or what, at least, it does not know to be a truth, must go on repairing its defects by other fictions.

But further, and admitting what this hypothesis demands, that the atoms of matter are inconceivably minute, that they are spheres, if that hypothesis pleases, and that the cube of platina contains twice as many of those as the equal cube of silver, there is yet much to explain; of which it can give no account, other than that which is, still, a new supposition, or fiction. They adhere into a continuous solid, through the attraction of cohesion: but why is that not of equal force in both these cases, or why does the silver not become platina? Repulsion is united to attraction: it is the same solution as in the analogous cases of pure Chemistry: but if it is a phraseology that sounds well, it is, like all before it, one that will not bear dissection.

Every particle of matter possesses an attraction and

a repulsion towards every other particle : we may grant even this ; whatever difficulty we may find in explaining this union of opposed powers. Matter then, being but one thing, it is in the different ratios between the attraction and the repulsion, that we must seek for the efficient causes of silver, and of platina : the proportion of the repulsion is, in the former case, double of what it is in the latter. Or, extending this reasoning to the whole of the consequences of this hypothesis, if attraction be taken as unity, every substance, inasmuch as it differs in weight from any other, is nothing more than a power of repulsion, bearing, to unity, a ratio inversely proportioned to its gravitation. It is obvious, that the more refined hypothesis of Boscovich, only renders the matter more incomprehensible ; if that can be : as it must also be apparent to every one, that the success of all these hypotheses, including that of light, has arisen from the generality of the terms in which they have been stated, and the unquestioning boldness of the assertions. Men have read and believed, as they read and believe in every thing : while the whole fabric dissolves into air, the moment it is submitted to investigation.

If this is a sufficient popular sketch of the hypothesis, it is also perhaps sufficient to show its inadequacy to explain the different gravities of bodies. If it were correct, two simple bodies at least, such as the metals, possessing the same specific gravity, should be the same substance : or, they ought most to resemble each other when they approximate most nearly in weight. Yet this is not the fact. Or, in any case, where actual cavities, or “ pores ” cannot be found, bodies of the same specific gravity should be identical substances. But if

this difficulty be still eluded, by presuming on incommensurable pores, the hypothesis must still explain what occurs when heat is added to any such body. This is the cause, or the supposed cause, of repulsion: it appears to be decidedly such in chemical actions: it is such with relation to the mechanical properties of bodies, when it enlarges their dimensions, and thus reduces their specific gravities. The natural question then arises, why does it not change their natures also? If the specific gravities of two metals, not far differing from each other in this respect, should be equalized through unequal temperatures, this would be the precise case of repulsion, united to attraction, in the particles, which, according to the hypothesis, must constitute those very substances; yet assuredly, no metal would thus become another.

The difficulties increase rapidly, if, passing from the mere question of weight, I examine those properties of bodies which relate to their cohesion, independently of gravitation: and that I may not be compelled to recur to this subject of our ignorance again, I shall proceed to note a few of them now.

If the hypothesis be the truth which it has passed for, every one of these properties must depend on dispositions, or proportions, between the attractions and repulsions of identical atoms; since matter is presumed to be an ultimate, single reality, when it is admitted to exist at all. I may then apply, as before, a specific solution to specific facts; for in this must the test of truth be ever sought: though I need not seek far, when a very few of the most familiar will suffice to show the utter fallacy of all this false yet received philosophy; received too, on authorities which it would be policy, if it were not modesty, not to name: such cannot fail to be their weight.

If I take the property of hardness, or impenetrability, the substance may be steel. The imaginary atom of matter is perfectly impenetrable, or is, in the most complete sense, a solid. The known body, therefore, which approaches nearest to impenetrability, should also form the nearest approach to a perfect solid. Therefore, it should contain the greatest number of solid atoms in a given space, and, consequently, ought also to possess the greatest specific gravity among similar bodies. Yet steel is not so heavy as lead, which is among the most penetrable of the metals. Or, if viewed in another manner, the tenacity of steel is enormously greater than that of lead: as that property is but another term for cohesive attraction. Yet, according to the hypothesis, it is cohesive attraction, or the near proximity of atoms of matter, which causes lead to be the heavy body which it is: whence, it is under greater powers of attraction compared to repulsion, than that metal which is, practically, under far higher powers of attraction, as its superior cohesion proves. If it be said, that in lead, the particles are more nearly approximated, but not equally retained in approximation, this would be a self-contradictory solution, under any notions that we can form of attractive force.

Should I examine the properties of bodies under brittleness, rigidity, flexibility, and elasticity, similar difficulties arise, even though excluding all consideration of their specific gravities. The cases of elasticity are peculiarly abstruse: and though mathematics have been most ingeniously applied to the facts, it must always be recollected, that although truth may be elicited by calculation, under certain assumptions, that does not prove the assumptions themselves to be true. It is the

greatest beauty of this most beautiful science, that true results can be produced by the comparison of imaginary quantities. But however ingenious any hypothesis may be, it is worthless if it cannot explain obvious facts.

The atoms of elastic bodies are removed to certain distances, by a repulsion such, that an external force overcomes it, as long as that acts; when this innate quantity of repulsion again exerts its power. It must be a feeble repulsion in glass or ivory which can thus yield: and why then does the cohesive attraction not overcome it, and destroy the elasticity? And if all matter is one, how is it contrived that there should be repulsions of so many characters as must exist in these and similar bodies; and how, especially, is it, that there is a yielding and a non-yielding repulsion in the same body, since no power can condense glass, so as to give it a greater specific gravity? Or how does this hypothesis explain the difference between brittle and elastic steel, or between those and steel which is flexible and non-elastic, when the changes in the distances of the particles is little, or nothing, as the specific gravities prove? It may also be asked, if repulsion, as the opponent of attraction, is caused by heat, why is not heat given out in the temporary yielding of an elastic body, as it is in the permanent condensation of another? Nor is there anything which explains the elasticity of stretching. The attraction of the particles is partially overcome in this case, as the repulsion is, in that of compression: and yet, acting, as it is presumed to do, in some direct ratio of the distances, it becomes most powerful where it ought to be weakest.

It would be abundantly easy to accumulate difficulties of a similar nature, by attempting to explain, on

this hypothesis, such combinations as that of impenetrability, or hardness, with frangibility or want of tenacity, occurring in the case of hard steel, and, under other modifications, in glass. Or, the union of such hardness with elasticity, in a steel spring, of penetrability with an unaltered specific gravity in the same metal, or of absolute and similar softness, with a similar specific gravity, in two bodies, of which one is permanently yielding and the other elastic. If I need not accumulate such difficulties, I am fully aware, from minute and special investigation of this subject, in the metallic bodies and some others, that these facts are connected with certain internal changes, or arrangements of minute parts under the laws of crystallization; but if this be a cause, we are equally unable to explain its operation; as the ulterior difficulty still remains.

I must here add a remark on a connected subject, and for the same reasons; that we may not, through fictitious explanations, acquire the habit of forgetting the Power which commanded those properties of bodies. If the usual mechanical explanation of transparency were the true one, either the theory of light or the corpuscularian hypothesis is false, as philosophers ought to have seen. The vulgarity of this solution is especially condemnatory of the hypothesis: as the poverty of this resource, shows the weakness of that philosophy which could adopt such an expedient.

Porosity, to have any meaning, implies a distance between two neighbouring solid parts; while that distance implies a low specific gravity, and should further imply defect of hardness and tenacity. No four bodies can well differ more than air, water, glass, and the dia-

mond; the latter, especially, being the most impenetrable body in existence, though of a very low specific gravity compared to the penetrable metals. Yet all are transparent: as hundreds of bodies, which must be porous, in the sense of the hypothesis, from the small quantity of matter which they contain, are opaque. When it is answered, that the pores transmitting light are incomprehensibly minute pores of texture, these must be rectilineal channels; and since they transmit light at every point and in every direction, it is obvious to ask, how such channels can be so disposed, and where the solid parts are, and how also the agitation of air and water, and the contortion of glass, do not destroy the transparency of those bodies? This objection, I admit, is coarse and mechanical: but the hypothesis itself is no other, and is thus fairly answered, on its own grounds. If it chooses to assert that there are ultimate pores and channels, not subject to such actions, this is not the same hypothesis; or rather, it is to use words void of all meaning. I am quite aware of the ingenious solutions of refraction, and especially of double refraction, which have been given on these grounds; as it is possible that they may hereafter lead to more accurate knowledge: but, in the mean time, the difficulties thus stated remain as they did.

I will yet add a few words on this hypothesis, though partially stated in the chapter on Light; and, for the same reason, that in the parts as in the whole, every speculation which tends to suppress a consideration of the Supreme power and First cause, has a pernicious moral effect; while the evil is unbalanced by any philosophical good, rather indeed tending to check the pursuits of science. It presumes that every thing, air

water, earth, the chemical elements, and even light itself, are essentially the same substance, under the term matter, and that all their differences depend on the quantity of that which is comprised within a given space, though still admitting the necessity of motion in certain cases, as in that of light. That an unphilosophical reader should conceive iron and the material of light, for example, to be the same thing, or that the latter is no other than the former, highly diluted by the mysterious power of repulsion, is not possible: it is to excite in him that repugnance to philosophy, which has so often vented itself in contempt, and, as the history of science has proved, with ample justice. And if there is a philosophical reader who is willing to believe what he cannot understand or explain, he must not at least be indignant that he does not satisfy others: least of all, that a writer of his own party sides with the ignorant, in refusing to ask for their belief in what he does not himself understand.

But I need not pursue this subject further. My object is not, either to detail the corpuscularian hypothesis or to controvert it; but it was necessary thus to state its imperfections, as an introduction to the following remarks. I must otherwise have referred to it where it was less convenient; or my silence respecting it might have induced the reader to suppose, that in referring to the First cause, I had purposely suppressed the mention of secondary causes, long received by philosophy as real ones, and to which therefore he would still have looked. That it is an hypothesis as purposeless as it is clumsy and imaginary, must be apparent to every one who will reflect. If the authorities for it, and the believers in its truth, are of the highest in mathematical

science, the only answer is, that authority which fails to prove, is nothing ; while it cannot even command respect, when its explanations are insufficient, or unintelligible, or self-contradictory.

The philosophical result of this may indeed be painful ; since it is the confession of our ignorance. The properties exist, and their causes, the immediate or secondary ones, are unknown. But it is the business of science to investigate these ; and, to this does Natural Theology urge philosophy, that it may hereafter be able to point out what it cannot now do, the wisdom of the Deity in His contrivances and laws. It cannot, however, receive fiction as the basis of its inquiries into that wisdom : while, in the meantime, its duty is to point out the wise results, and, unable to discover the mode of execution, to look directly upwards to the Hand that executes, in whatever manner.

One observation more on this hypothesis, and I shall terminate these introductory but indispensable remarks. Its simplicity has been matter of boast. That would be a valuable property, were it proved, and if, under that simplicity, the facts could be explained. Yet neither is the case. But if I have often shown that simplicity of proceeding is not the invariable rule of conduct with the Creator, it is certain also, that an evil use has sometimes been made of this doctrine. With respect to ourselves, the extreme of simplicity would leave little to contemplate and examine. It is in multiplicity that we find actions and results : to trace these to causes is the exercise of our faculties, as it is also the study of the Creator's wisdom. Or if powers of mind of the highest order can study this wisdom in the real simplicities of Creation, the limitation of those powers

is very narrow ; while, to the great multitude, such facts would be without effect or value. Let us also not forget, that simplicity is that dangerous step towards no cause, which has been a philosophy of Chance or Necessity, at so many periods. Under a much more moderate view, it removes the agency of the Deity to such an indefinite distance, that we cease to observe His government, or He becomes that dormant Supreme, of the Aristotelian philosophy, of whom I have so often spoken. It is by connecting His power and agency with His visible works, that we learn to see Him in every thing : as, in the present case, I can securely do this, without contravening the rules of philosophy, either by the omission of secondary causes, since these continue unknown, or by assuming non-existent ones, since that which I have thus written is intended to exclude those.

I may now proceed to notice the obvious applications of these several properties of matter to the purposes of the Deity in Creation. But I must, as usual, select from an enormous mass of facts ; since these properties, in some manner, include the larger part of all the bodies and actions in the universe, while many of their effects have also come under review on different occasions. If the whole of the properties in question occur only in solids, so have the remarks already made on the atmosphere and on water, superseded the necessity of including here, those particular forms of matter. The terrestrial solids may be divided into two great classes, the organic and the inorganic : and, under each, there are, with little exception, two divisions also, by which they may be further classed. In the organic division, the two modes of solid matter are the animal and the

vegetable compounds ; each of which is strongly distinguished from the other, although, under both, there are many varieties, attended by remarkable differences of mechanical property. The inorganic class is chiefly divided between the metallic and the stony matters or earths ; the difference betwixt the two latter being chiefly a question of magnitude ; while, if the saline substances do not well unite with either, they form but a very insignificant quantity in the whole.

The organic substances, in both classes, are chemical compounds, sufficiently complex, the general nature of which is familiarly known. In each also, through all the kinds of organization, and through all the parts of any one of those, the same general chemical substance is found, if under certain variations, and with some occasional additions from the class of inorganic bodies, for special uses, as in the cases of teeth, bones, shells, and nuts. Not to recur to the very obscure or doubtful ultimate visible structures in these, the various requisite properties, in the several parts of any structure, are communicated under the attraction of cohesion. Thus we find rigidity, elasticity, and so forth, precisely where each is required : and I shall immediately have occasion to note, how remarkably different degrees of cohesive attraction, or tenacity, have been appointed, even to the same chemical compound and mechanical structure, where the different magnitudes or offices of different organizations demanded those. The hypothesis which I have thus noted, would have been troubled with this great fact, had it been known ; as it is now, I believe, for the first time pointed out ; obvious, nevertheless, as it is. It would, in itself, be a sufficient proof of the unfounded and inefficient nature of the common

doctrines of cohesive attraction; as it is, of our entire ignorance of this subject.

The inorganic bodies, which are either compounds or simple substances, exist also under the same cohesive attraction: to which, in different degrees, and modified into all those obscure properties already mentioned, are owing all the distinguishing qualities which they possess. But in these, there is a peculiar modification of this attraction which does not exist in the organic substances, except in the case of teeth and shells, with a few other rare ones in the vegetable division, such as the bark of *Equisetum hyemale*, where mineral bodies are associated to the organizations. I allude to crystallization; with which I may here unite that less regular and definite mode of cohesion into peculiar forms, which constitutes the concretionary structure in rocks.

If I rank these under cohesive attraction, the whole subject is so utterly obscure, that science can as yet offer no explanation, though enabled to determine, and even to anticipate the forms produced under a regular geometry. To say that the attraction of cohesion and that of crystallization are one thing, cannot be accurate language; since there are tenacious and weighty mineral bodies which are not rendered such by crystallization, however internal, minute, and obscure, it be imagined: though every one of them has been, or may be found in a crystallized state, or is susceptible of crystallization. And setting aside the geometrical forms, we find this important, though obscure fact, connected with some of the peculiar properties of these bodies; namely, that an internal geometrical disposition of some kind does often exist, that it may be changed,

by means of temperature, and that under such changes, the mechanical property becomes altered; as is especially notorious in steel. But whether this be connected with the cause of peculiar properties, or how it is so, if it be, is what we do not know. Yet this at least is certain, that crystalline disposition and cohesion alone, cannot be the source of any of those properties; because, if it were, many of the most dissimilar minerals would possess the same qualities, from the community of their crystallizations, and because we find the very same properties, such as elasticity for example, in organic substances where nothing like crystallization exists. These facts, interesting and valuable as they are, I cannot here venture to detail; as I may terminate these slight but indispensable remarks on the general nature of solid bodies. If, once more, the whole is but a picture of our ignorance, it is that of the Creator's power; ever effecting whatever He desires, even when so concealing His means, that without experience, we should not believe in the results: so improbable, and often impossible, do they appear.

In commencing with the gravity, or weight, of solid bodies, the first fact that strikes us is, the great differences among them, or the very various specific gravities of the substances known to us: of the cause of these differences, I have already said that we know nothing, however convenient the phrase "quantity of matter" may be. It remains therefore to inquire of the utility, or the final cause: on the general presumption, first, that nothing has been thus appointed without a purpose, and next, from a certain extent of experience, through which we trace good ends.

The general use of gravitation is obvious: of the

utility of the numerous distinctions in the quantity, we are often much at a loss to conjecture: but that needs not prevent me from noticing those when we can see the purposes. A very heavy body is a source of stability: its high specific gravity is the opponent to external forces, or impulses through motion: and under this case, the use of stone in architecture is an obvious example. The same property allows one body to be used in a small quantity, to oppose the gravitation of a much larger mass of others; and, in art, the applications of this are as various and useful as they are familiar. Thus also does a high specific gravity become applicable to the production of motion; and further, to that of momentum: while, of the uses derived from these things, the instances are also too familiar to require quoting. The consequences of relations among specific gravities are, however, most remarkable in those cases where water and air take a part. The repose of mineral substances beneath water, arising from this cause, if it be of value in works of art, is of much more important use in the preparation for new land and future rocks; as it is here needful to notice an exquisite nicety in the adaptation of the specific gravities in this instance, since the ends in question could not have been gained without it.

The difference is such, as, while it ensures a sufficient stability, does not check a limited motion: and thus are the solid substances transferred and dispersed to that precise extent which the result proves to be the best, and which, unquestionably, was among the designed adaptations of Creative Wisdom. To this relation also between solids and water, we owe the power of flotation, yet under a reversed proportion: as in this case also we

derive, practically, even greater aid, through the different specific gravities of air and water. In the case of the atmosphere, however, the changeable relations of gravity between that substance and water, are the most remarkable; since on these mainly depend the great facts that belong to rain.

The appointment of peculiar specific gravities for animal substances, and structures, is under a much more complicated set of adaptations; since the weight is engaged with two distinct relations, instead of only one. A certain stability was necessary to resist external forces; but it demanded also to be regulated by the moving powers of the animal itself. We ought to believe that the calculation is perfect: because we find the results such, that we cannot suggest an amendment. A greater specific gravity would have drawn too much on the moving powers: a less one would not have sufficiently resisted external force.

This, however, is but a general view: there is an involution of minor adaptations of specific gravities beneath the general one; though I need but barely notice here, for the sake of bringing these facts under one broad view, some of the examples which have already come under review, for the purposes. It was needful that terrestrial animals should be able to traverse water; and their specific gravities have been regulated accordingly, partly by that of their solid matter, and partly through included air. In the fishes, I formerly showed that beautiful adaptation of specific gravity which enables them to dispense with much muscular power, together with the varying subadaptations executed through the aid of internal air: and in the birds, the same nicety of calculation was equally shown to have been

made. Were I to proceed to specific instances in individual animals, the same calculation and contrivance would be perceived: but the reader whose thoughts have thus been turned to this mode of generalization, can now select the cases for himself.

In the vegetable department, the considerations under gravity are of less extent and importance, though the relations are not less complex. Here also a certain gravity was required, for the sake of stability, both as to the being itself, and the uses it was to serve for man. But the foundation afforded by the construction of plants, admitted of a specific gravity less than even that of water, as thence, further, is utility derived. Under their present construction, I may also remark, a greater gravity than the actual one would have demanded a greater tenacity, at least in the horizontal branches; while experience shows that this relation is perfect.

On all this, also, I need not dwell: but I must not pass from the vegetable material, without pointing out how ingeniously, or rather how wonderfully, a low specific gravity has been united to great strength; while the utility of this meets us at every instant. Whatever may be the immediate cause of the differences of specific gravity in the inorganic substances, we can often discover that this end has been partly, or partially, attained through an assignable mechanical structure, in the organized ones. Yet it is not thus attained in all: so that the same difficulty again returns on us. It is an arrangement of structure, very materially, in wood; in cork, strikingly, and in the feathers of birds: yet the minuteness and beauty of those structures, if they excite our admiration, do not assist us in explaining the results, when we find such cohesion, or strength and

tenacity under various modes, united to so small a quantity of matter as the low specific gravities, and also our power of compressing these structures, prove.

But I must quit a department of this chapter which I gladly leave to the reader's further illustrations. He has but to recollect, that a certain gravity, with relation to the earth, was necessary for the general unity of the globe and the stability of its parts, that a variety of gravities were requisite, under certain other relations and purposes, and that all these were to be combined, for other ends, with every other quality of bodies, and often with more than one of those. With this general clue, he cannot be at a loss to observe and to reason : and when he has done this for himself, on the facts which meet him everywhere, he will not, I think, doubt, either the foresight, the contrivance, the wisdom, or the power, which, even where, to ignorance or carelessness, all seems accident, has left nothing to chance ; which, in all that appears, from its obscurity, to be indefinite and uncertain, has acted with the same precision as in those purely mechanical arrangements which are tangible to our limited apprehensions.

In passing from the attraction of gravity to that of cohesion, as the leading bond of all the other properties of bodies, the most obvious subject under it is strength, under the form of tenacity. I have already said, that our philosophy cannot explain the cause, that it bears no necessary relation to gravity as another mode or result of attraction, and that it is still a mystery. Here then, it can only be viewed, in the bodies in which it occurs, as an arbitrary appointment of the Creator, and, as we may safely assume, for certain ends. Those ends, that utility, we almost always perceive, and

thus justify the appointment: when we do not, we have no reason to suppose that they do not exist. And if I formerly noticed the peculiar mystery of this appointment, in the case of the minute animal structures, it is that case, especially, which, while it confounds all our philosophy, can leave no doubt respecting the intention, any more than the power of the Creator: as deeply incomprehensible in this little and single instance, as in anything which occurs throughout the universe.

As that force of cohesion which constitutes tenacity cannot well exist without some other of the properties of bodies already enumerated, I must consider it in connexion with those: as it is even useful to do so, since it is through such combinations that the several ends in question are attained. But it is important to remark, that those connexions are arbitrary, in the same sense in which I have so often used this term: or, philosophy seeing no necessary connexion, there is nothing at present left for us, but to view them as pure acts of the Creator's will, intended for certain ends. And, among other instances, this is illustrated in the case of iron under its different modifications: including among those, steel. This substance, and with scarcely an alteration of its specific gravity, will maintain nearly the same tenacity, or strength, or the same power of cohesive attraction, under that hardness and impenetrability which divides almost all substances and is divided by very few, under a frangibility which yields to the slightest impulse, under a rigidity which yields only to the force which breaks it, under a softness which itself, under other conditions, penetrates with the greatest facility, under a flexibility which assumes and retains

any impression, and under an elasticity which is nearly the model for this singular quality.

That, also, which occurs in this single substance, under internal changes, which, though we partially see them, and know how to produce them, we cannot explain, is found in a great number of the solids throughout Creation, be they simple bodies or compound ones, organic or inorganic. And in the great majority of instances, these combinations of properties are not changeable, as in the case of iron, but permanent: or, there is given to a particular substance, a peculiar combination, of two, or three, or more, of those properties, and also under subsidiary variations: so that every one of them possesses some definite character of its own, by which it is distinguished from all others, and from which its peculiar uses are derived.

Thus do we find endless diversities of weight, united to powerful and to weak cohesion, to impenetrability or hardness, and to the reverse: as we find the cohesion which constitutes hardness, without that which produces tenacity, or a cohesion of tenacity united to rigidity, or to flexibility. Thus also is there a cohesion of hardness, combined with elasticity, or a feeble cohesion, producing softness, similarly combined: so that an elastic body may be rigid, or flexible, or soft, or hard, or light, or heavy. If these are things which show the utter futility of all hypothesis, why have they not been noticed, where they could not fail to be known? It is not philosophy which does not see such facts, and it is worse than philosophy which, seeing them, determines to pass them by. Thus also, under inferior variations, we find longitudinal without equivalent lateral cohesion, or tenacity united to brittleness, independently of organic

structure ; with far more, of which examples will immediately be pointed out, and all equally inexplicable.

It is by the communication of such properties to different bodies, that the Creator has gained the ends which He had in view. The separate ones, as I formerly enumerated them, are efforts of Power, and the more striking to us, as we cannot explain the means. The combinations of these are still more wonderful : though in using this term, it is assumed that the leading properties are truly distinct, and, thus, a kind of secondary causes : which is to assume what we do not know, but which is a convenient supposition for the present purposes. And thus, adopting that view, as a mere expediency, I may proceed to a few examples out of thousands, since I might extend them to almost every substance in nature.

In the metals, we find the cohesion of tenacity united to almost every other property of bodies, in various degrees, and in endless varieties of combination. I have already noticed the remarkable case of iron, where the tenacity is fundamental, and also very great. In copper it is less : nor is it there susceptible of the same numerous and varied combinations. In arsenic, it is evanescent ; and here, nevertheless, there is considerable hardness united to frangibility, constituting brittleness. In lead, the cohesion of tenacity constituting strength, is small : yet there is the reverse condition, or that of softness, united to it, producing a tenacity of a very different kind, which there is no sufficiently definite term to express and distinguish. This kind of tenacity, further modified in some unintelligible manner, gives to gold its property of minute lamination and extreme ductility : while the same qua-

lities occur in silver and copper, in inferior degrees, and, in still lower ones, in lead, tin, and iron. And in some of these cases too, there is one of those still inferior modifications of tenacity, of the cause of which we can give no account. The union of tenacity and softness which confers the property of lamination is not precisely that which gives ductility, as is familiar in lead, tin, and more. Under what varieties these properties are united to different specific gravities, and how unexpectedly, I need not again say : as I may suffer the reader to fill up this short catalogue, from the familiar facts of Chemistry, which he will now probably contemplate in a very different light from that in which he will find them represented. From all these properties also, there are distinct uses, derived, or to be derived, it is probable, hereafter : while those point to an intention, or an efficient cause, in Him, the Creator, who has not yet allowed us to discover the secondary ones.

If I pursue the cohesion of tenacity through the other inorganic substances, we find it united to hardness or impenetrability in many rocks; to that hardness, with frangibility, in others; in some, to that peculiar mode of softness through which we obtain toughness; and, in all, to certain varying qualities of elasticity, even under the union of this with considerable flexibility. Here also, we often trace the uses, if we cannot do that in every case. From toughness, we derive peculiar useful applications; and thus also do we find this, under certain textures, producing particular modes of tenacity. If strong cohesion and hardness were necessary, for obvious reasons, so was frangibility indispensable, to permit that destruction through which the rocks are the sources of new lands and of soils. We seldom note the truly wonderful combinations of properties through

which results so apparently contradictory are derived. An incalculably small mass of stone will bear the weight of the Andes, but a moderate blow will shiver it into fragments. A similar mass of iron would be compressed by that weight ; but no impulse would break it, or separate the parts. In the stone, in each case indeed, this is a singular combination of properties : and it is all produced under mysteries which we cannot explain. Mathematics indeed, in the case of the stone, offer their solution, in the difference between impulse and pressure, under the laws of motion. But that is only the expression of a fact : it does not teach us what is the constitution of bodies subject to those actions in this manner, what are the causes whence those two modes of force produce those different effects. It is not merely that a given velocity may be superior to any given pressure, as in the ordinary communication of motion, since it depends also on another correlative law, or constitution, in the bodies themselves, of which we know nothing ; since, in calling it a vibration among the parts, we are no nearer to a solution. Of this, the extreme case occurs in the frangibility of unannealed glass ; through a contact which it would be an abuse of terms to call impulse. But, in the case of stones, both properties were necessary ; and they have been combined by Him whose resources are without bounds. I need scarcely repeat, that under the common doctrines of cohesive attraction, the union of two such properties implies a contradiction in terms : since it is a large quantity of this power which produces the hardness, when it must be a small quantity which permits the separation. Of such value is all this philosophy.

If I pass to the organized bodies, the combinations of the cohesion of tenacity with other properties, offer

an even more interesting set of facts : of which, many however, have come under review on former occasions. The present object, nevertheless, being general, I may select, without any regard to this.

The great fact of the tenacity communicated to the minuter animal structures, I must therefore notice again : remarking, further, that it exists without respect to hardness, or softness, or any other property ; since it occurs in membrane, and tendon, and muscular fibre, and horn, and bone. It was needed in all, and it has been given to all : as if it was independent of everything else which we choose to rank under the sweeping term attraction. As it exists in feathers, it is not less a mystery ; especially as it is there united to the least quantity of matter, or the least specific gravity, and is also utterly independent of vitality ; remaining equally in the dead structure. And here also, under different circumstances, it is united to flexibility or rigidity, combined with elasticity, or not, and further, in the case of quill, to a degree of hardness or impenetrability, which is not less marvellous than all else, considering the small quantity of matter contained in that substance, if the quantity of matter is really to be judged by the power of gravitation. But I have elsewhere expressed, respecting this assumption, doubts which will shock or surprise those who have taken all which they read for granted, and who have not perceived that they had been cheated by an identical proposition. That matter must gravitate, of necessity, is the prime assumption : that the gravitation is proportioned to the quantity of matter, is not merely a further assumption, but a nugatory proposition.

But in the stings, or other perforating tools, of the minute insects, this union of hardness and tenacity with

a light, and, in other cases, a very feeble substance, is infinitely more remarkable, as is proved by the effects ; since, under a specific gravity not much greater than that of water, these instruments exceed, in both properties, the strongest and hardest metals. To deduce from this, and other facts, our utter ignorance of the nature of cohesive attraction, is of little value, compared to the higher conclusion which seems to flow from it. If, anywhere in creation, we can draw such an inference respecting the Deity, I think that we can safely do it here. Whatever this attraction may be, it is, under all its modes, a power in His hands, as independent of all secondary causes as gravitation is, retained by Him, and distributed as it was required, in any and every form, and for every intended effect, without any regard to any other properties or forms of matter. Thus may the attraction of cohesion be utterly independent of even that of gravitation ; much as philosophy has confounded or united them : as the very simple, and apparently trifling, if unnoticed facts, that I have thus quoted, seem to form an absolute answer to this hypothesis of long reception. And, in this view, it is an arbitrary law, or act of His will, as much as is the imparting of life : while, if this be admitted, we can never approach nearer to the knowledge of causes, inasmuch as there are no secondary ones. Neither chemical analysis nor microscopical investigation can discover any differences in the membrane, the tendon, or the bone of a small animal and a large one. They are identical under every relation ; and yet, in the one, we find tenacity, rigidity, hardness ; exceeding, not a hundred times, but many thousand times, what we find in the other. Or, though there were chemical or mechanical differences which escaped us,

they could never amount to nearly this ratio ; so that the inference remains the same. It was necessary, and He has so commanded.

It is the same, under modifications, in other animal structures. It was necessary that bone should not be heavy, but that a certain bone should be inflexible and tenacious : it is both. It was necessary that another bone should be hard, impenetrable, another flexible, another elastic : and thus we find similar gravities, under similar materials, united to hardness, tenacity, flexibility, rigidity, elasticity : to one or more of these, and without being able to satisfy ourselves that there is any very adequate reason but the final cause.

It is true that we do perceive immediate causes for some of those effects, as in the proportions of earthy matter in some bones, and in the peculiar chemical compound which forms the enamel of the teeth : yet these cases are not sufficiently numerous to vitiate the general argument as I have here stated it. Between the elastic and rigid, and the flexible and soft hairs, whether in the same animals or in different ones, we find no essential differences, or none that will account for the results ; as is equally true of feathers and far more. The tooth, just quoted, is one of the remarkable cases of a combination of properties. It is harder, against penetration, than iron, as it is far lighter ; and it will penetrate that substance as flint does, while far less frangible than this mineral. The suspensory ligament in the neck of an ox, is as tenacious as bone, though containing no mineral substance ; while it is also flexible and elastic. In the coat of the eye, there is extreme tenacity, united to softness : in cartilage, a low specific gravity is combined with a singular union of softness

and impenetrability, with great tenacity in every mode, and with a very peculiar elasticity. And thus also, where the elasticity of compression was especially needed in this substance, it has been given in an unusual degree to the inter-spinal cartilage.

The vegetable solids produce instances in abundance, of the same kind, and under the same difficulties of explanation, notwithstanding all attempts to refer them to mechanical arrangements. The extreme of tenacity occurs in such fibres as those of hemp and flax; while, in these and many other cases, it is united to a low specific gravity, as in some of the animal solids. Sometimes too this tenacity is united to rigidity, at others to flexibility; as either of these may be further combined with elasticity or not. But I need not prolong this chapter, by special instances of these qualities from this department of Creation; as the substances of this class, together with their properties, are familiar to most persons. The general reasonings are still the same: and in seeking for the ends, we sometimes find them in certain wants of the living plant itself, at others, in the uses which those substances serve to man: while, on the latter, I may refer to a future chapter (c. 44) for what I should otherwise have said in this place.

If in thus treating of tenacity as the obvious result of cohesive attraction, I have almost sufficiently noticed the qualities of hardness, softness, brittleness, toughness, flexibility and rigidity, as being, all of them, properties dependent on or connected with this, in an apparently immediate manner, on whatever inexplicable circumstances these combinations may depend, I must still bestow a few words upon elasticity, on account of the still more abstruse nature, if possible, of this property, and also because of the great uses which it serves.

If this is a peculiarly mysterious quality in solid bodies, the variations which it displays and the combinations in which it is found, are not less sources of difficulty; while on the latter, I must add a few remarks to those already made. It occurs both in the organic and the inorganic solids: and, in the former, we can generally, if not always, trace the reasons for it, in its uses, if it is sometimes difficult to discover these in the latter case.

In a popular and practical view, there are two modifications of elasticity; that which occurs in bodies under compression, and that which takes place in extensible substances. And, sometimes at least, the former is found without the latter; while, if it is less certain that the elasticity of extension can exist alone, there are cases, where it is difficult to show that any elasticity of compression is present.

Among the inorganic bodies, this latter is found in the stony substances, though in different degrees; nor am I aware that the use of this provision can at present be assigned. Yet, as it does not appear to be a necessary part of their constitution, inasmuch as it differs in many, and is also not universal among the metals, there was probably some purpose in view, which a more ingenious searcher into final causes may discover; unless, indeed, this kind of elasticity be essential to that of frangibility, the uses of which I have already noticed. Nor is the utility of this kind of elasticity very apparent anywhere, if I except certain cases in the animal mechanism, whether in the organic or the inorganic bodies, where it occurs; in each division of which, ivory and glass are remarkable examples, from the great perfection in which they possess this property. If we

do derive some trifling services from this quality in certain bodies, I know not that these can justify the assumption of such a final cause ; particularly as the utility bears so small a proportion to the extent of the provision. Inasmuch however as the elasticity of solid bodies is a source of sound, we can see one special use, if we cannot apply this inference to every instance.

In both divisions of substances, the useful ends attained through the other modification of elasticity are far more apparent. In the inorganic ones, however, the uses are limited to the service of man : while this end of the appointment ought not to be refused, when the substances themselves have scarcely an existence but through his labour for his own purposes. If the Deity thought proper to create the metals for the use of man, it is not a fantastical seeking after final causes, to believe that He also gave them their peculiar properties, and this among the rest : while, as I wish that the reader should learn to face these questions, instead of shunning them, I would rather that he should consider even the singular property of a steel spring, by which its isochronous vibrations become a measure of time, as among these final causes, than suppose this most valuable consequence the result of contingency, unforeseen and undesigned. But the utility of this property in metals is as extensive as it is much too familiar to require enumeration, under all its applications to the mechanical arts.

The use of this kind of elasticity in organic bodies is, however, far more extensive, and under a greater variety of applications : since it is not only a frequent provision for the uses of man, but is essential to the very existence of those bodies, as living beings. Many

striking instances however, have already been brought before the reader ; so that I need, now, but barely note a few, for the sake of that general view to which I have here limited myself. This valuable property has been pointed out in the vascular system, especially in the arteries of animals, and also in their cartilages, ligaments, bones, and membranes, as well as in such parts as hairs and feathers ; while, according to the required uses, the mode of the elasticity varies. Thus also has the existence and use of elasticity in the vegetable structure been noticed on various occasions ; in the power of resisting, or rather of eluding, external forces, which it gives them, in the dispersion of their seeds, and so forth ; of all which, it is now sufficient to remind the reader. And with respect to the uses which man derives from this property, or from the others treated of in this chapter, in both classes of the organized substances, I may refer to a future one (c. 44) : and equally to the 45th, for various uses derived from the inorganic substances, under the same diversities of quality.

Yet I ought not to conclude on this property, elasticity, without one general remark. Let philosophy attempt to assign the cause as it may, no philosophy could, by any *à priori* reasoning, have expected to find it in the discordant bodies in which it exists, and in which it often exists without a shade of difference in power or manner, where the substances themselves are opposed in almost everything else ; in chemical constitution, specific gravity, and much more. Steel and feather, cartilage and stone, nothing can well be more discordant in everything else but this property : while, finding it, under various modes, in things so discordant

or different, as ivory, caoutchouc, glass, ligament, metals, wood, horn, and so on, without any apparent regard to hardness, rigidity, weight, toughness, flexibility, softness, discerptibility, levity, we are again forced to conclude, that it was an arbitrary appointment of the Creator, designed to gain the ends that are attained. It is certainly a very unscientific conclusion, that elasticity is, or may be, a simple and single property, independent of all other properties in bodies, and communicable as communicated, to many different ones, just as we can suppose magnetism given to iron. Yet should any one maintain this, science would now be much troubled to disprove it: while even philosophy is compelled to join with the vulgar, in admiring the power which could deal with matter in such a mode, be the immediate cause of elasticity what it may.

Thus may I dismiss the consideration of those mechanical properties of bodies which I enumerated at the commencement of this chapter; trusting that I have done enough to display what I intended, the wisdom and power of the Deity, as well as that beneficence which is proved by the uses of these arrangements.

It would still, however, be more easy than expedient, to extend this sketch to the consideration of some other properties, or arrangements, or laws, which concern these several bodies, and which do not fall under the heads that have been enumerated. Such are, expansibility and the reverse, under temperature, such is friction, and such are the laws of motion and of resistance, under a great variety of circumstances: laws of nature as they are termed, or rules of action appointed by the Creator, for specific ends. How highly interesting all these are, I need not say; deeply as they are concerned

in all the actions of bodies on the earth, and deeply as they often interest ourselves ; while affording also ground for much valuable and pleasing illustration of the great subject before us, in the display of remarkable or singular provisions, of wisdom as of goodness.

On those things, however, I can but venture to hint at such facts as the effects of expansibility in producing the circulation of air and water, those of friction in disintegrating what it was intended to destroy, and in conferring stability under innumerable circumstances, including the retardation of moving machinery, with those of the composition and resolution of forces and motions, so widely applied in the case of animals, and so widely also useful to man in the conducting of his own works. Many of the most interesting facts have already come before the reader, in some form : and did I attempt to pursue these subjects further, under the present general views, the considerations become too abstruse for a popular work, as they would often also lead to repetitions, which have, unavoidably, already been but too frequent. I must therefore be content with suggesting the whole circle of these powers and actions to the reader's own reflections, as far as he may know, or have the means of knowing them : since, were there even space, I could not here write for those who do not know. Of such a reader, it is the philosophical duty to trace these effects to the specific laws or appointments on which they depend : but it is his moral duty to examine the knowledge, the wisdom, and the power, under which they have been established, together with the beneficent results which they produce. He may be assured that he will ever find, in such views, a material addition to the pleasures which he may derive from

philosophical investigations, even in a philosophical light; should they produce no better effect, or confer no satisfaction derived from a higher source of contemplation: since they serve to give an interest to inquiries which too often terminate in vexation or disappointment, when they evade our attempts at explanation, or surpass our comprehension. Should even no better effect follow from a reference to the First Cause, than that rejection of fictitious or hypothetical secondary ones, of which I have, here and elsewhere, given examples, it will not be a small gain to mere philosophy; when the conviction of fallacy is the indispensably first step in the search after truth.

CHAPTER XXXIX.

ON THE CELESTIAL MECHANISM.

I HAVE chosen the term *Celestial Mechanism* in preference to the word *Astronomy*, adopted by writers on Natural theology, because it much better expresses the object of this chapter. The universe is indeed a divine and inimitable mechanism; but it is still a pure machinery, if we exclude light, heat, electricity, and magnetism, together with chemical action, as supererogations to the fundamental structure. It is a great machine, or a collection of many machines, dependent, probably, in some manner, on each other, so as to be still the constituents of one great piece of mechanism. Our own machines consist of bodies and of motion: and the laws of mechanics by which they are regulated are those of abstract matter and motion. It is the same in the great universe. Though chemistry were at rest, though light and heat did not exist, the machine of the universe would still be what it is; and hence is it the object of mathematical demonstration, as it is that department of creation to which this is peculiarly, if not exclusively, applicable.

Thence the convenience, not less than the logical propriety, of considering the universe in this light, and of separating from it whatever belongs to other sciences,

or other laws than those of mechanics. Without this our inquiries become confused ; as we also mix up matters of rigid demonstration with far other kinds of evidence or illustration. Such has been the error of former writers on natural theology : and hence also, among other things, have arisen the passages of irrelevant declamation in which they abound, and their misplaced attempts to excite our separate admiration of things which are but portions of the general design ; appointed consequences involved in that which is the real subject of admiration.

Through what oversight a late writer excepted this subject, as ill fitted to prove Design, and as almost solely applicable to the proof of Power, it would not be easy to say. The truth is, that there is nothing in the whole range of creation which evinces design more perfectly, nor more perfectly excludes the possibility of chance ; if, more than aught else, it may be admitted to display power : yet doing this, only because our common notions of power are vulgarly associated with effort. And the design is a design of Wisdom. It was a difficult problem to associate so many bodies, of such various magnitudes, under such various motions, throughout so large a space, and under such approximation and intermixture, with the further power of affecting each other's motions, and still to preserve order and permanence : so to contrive the total machine, and all the involved machines, that nothing should become deranged, nothing want the repairing hand of Him who appointed them. It demanded additional wisdom to do all this easily and simply, since facility and simplicity constitute perfection in mechanics : it is simply, as it is perfectly effected ; and this is the depth of wisdom.

The celestial mechanism is therefore calculated to display Power, in all that relates to its magnitude and to the extent and velocity of its motions : as it evinces Wisdom in its arrangement and rules. The first we discern by our senses, aided by comparisons, almost without assistance from mathematical demonstration : and hence these proofs of the Power of the Creator can be comprehended by any one, by the vulgar as by the philosopher ; since each can see, and each add number to number, which is all that is here required. But if science is necessary to understand the Wisdom, that is no reason why the facts should not be stated, especially when we can say that they have been demonstrated. They cannot indeed be made plain to every one, by means of popular language ; but while most of our beliefs consist in trusting the belief of others, or the validity of evidence, so do we especially believe in mathematical demonstration, without comprehending it, when we are told that it is valid. But for this, indeed, there would be few believers in mathematical truths ; since not one in tens of thousands knows even the most common of those to be true, as, in the higher kinds, the philosophers themselves who follow Newton and La Place, believe these men because they say that they have proved. To show the wisdom and contrivance of the Deity in the great universe, is not therefore more improper than to display His power ; since the conviction of mathematicians forms the sufficient evidence for those who cannot themselves understand these. And, while to have separated the two attributes of wisdom and power in this case, would have led to inconvenient repetition, I shall commence with the latter, as being the most obvious.

Though I use the word Power, the usual term is Omnipotence. This however is vague in meaning, or a mere word, conveying no ideas, though it signifies the power of doing everything. We assent to this assertion of universal power on the part of the Deity, but we do not think of its meaning, because we do not reflect on the applications of such power; and therefore it does not lead us to think of Him, nor of the nature and extent of His command over the universe. But power is the capacity of doing something: and, of that capacity we must have proofs, or evidences in the facts themselves, that we may feel what it is. Or, if we would see and feel that the Deity really has power, as we would see it in a man or a machine, we must see what it is in effect: what it is that He has done. I must therefore commence, at least, by showing one instance of power, clearly exerted; as I must also show the quantity of that power, since it is, finally, a question of quantity. His power may be boundless, or infinite: we believe, *à priori*, that it is so: but we cannot prove an infinite, and must therefore prove a definite. The process then is, to add definite to definite: it is a sum in constant addition; as, further, with respect to Him, it must be a sum of infinite additions, or an endless series.

The end, therefore, is not attainable: but His power is always a sum greater than any assignable quantity, which in Him, as in mathematics, is the Infinite, or, in power, Omnipotence. In the physical case of the display of His power, it is true that we cannot conduct this proof to the same distance (approximation cannot be predicated of the infinite) as we do a mathematical series. The physical series escapes our senses, first: it proceeds to escape our powers of addition, or of com-

prehending the additions; and at last it passes beyond even the bounds of the imagination. But this is still the method of proceeding, for the purpose of comprehending the power of God: it is to appeal first to the senses, then to numbers, and finally to the imagination. And thus alone does it seem to me that the sense of great power can be impressed; while Omnipotence becomes a metaphysical conclusion, *ab absurdo*; since no limit can be drawn. It is the same mode of proof from which we infer infinite space or duration. And if the proof of Omnipotence ought to be thus conducted, if we desire that the power of God should be felt, as far as that is possible, the right process does not appear to have been seen, or at least, adopted. Its basis lies in the first term: in an act of power, simply, which can be seen, or in some way rendered sensible, so as to be appreciated. And on this ground I shall proceed.

Of mechanical power, we have a familiar standard, in our own; and it is the real object of reference in such cases. It is the proper one, especially, because it is associated with will, and therefore with life and personality. Man's force of arm is the proper point of comparison on questions of motion; and it produces a definite effect. We find a definite effect, or motion, in Creation, which we may attribute to an analogous power in the Deity, though that is merely His will: and thus we reason back to the power from the effect. It is the first term of the series in this case. It is nearly the same for space: whether this be mere space, vacancy, or filled space, bulk. There must be some familiar measurable standard; a mile or a league, a square foot, or yard, or a cubical one, or a pound or a hundred-weight; or the definite length from London to Paris,

or an acre, a territory, or the visible area of the horizon, or a pyramid, or a mountain.

On these grounds therefore I must attempt to show the power of the Deity in the great celestial machine, the universe of orbs. This comprises bodies, or bulks, distances, and motions, or velocities ; as it is under this last that we chiefly feel what is power, as to motion. The bodies are mensurable, and, because they gravitate, ponderable. To a sufficient extent for my purpose, they have been measured and weighed. The distances have also been measured ; and equally are the velocities known. Everything therefore is referable to the senses, or to experience, or can be comprehended by comparison with what is known, through addition, to a considerable extent at least : after which the imagination must be called on to do the rest.

Respecting the bodies of this great machine, I may put aside the question of the creation of matter : and for the sake of the assumed standard of power, consider them as made out of prepared matter. We ourselves make a globe, or build a pyramid, out of materials : I will suppose that the Deity acted in the same manner. In whatever manner or place He created matter, He formed it into masses ; and these are the constituents of His great machine. The first question therefore respects the quantity of matter in the whole : for, whether created, or merely collected into masses, the effort was very great. We are compelled thus to feel ; because we find that it requires great efforts to collect a very small quantity. To have formed large and definite masses out of it, is a still further effort of power ; because, with much labour, we can form but very small ones. But as we cannot by any means contrive to com-

prehend at one view what the quantity of matter in Creation is, I must state a single case, of one globe, first ; attempting afterwards to rise from this by degrees. And as it is difficult to dissociate the distances of these bodies from their bulks, we shall thus also acquire some notions of space ; which, without such aid, is equally a vague term, making no impression, or a superficial idea in which we immediately lose ourselves.

The second mode in which great power is here displayed, is the case of motion. The motions of the heavenly bodies are of two kinds ; consisting in those of gravitation, and in the centrifugal or tangential directions. The former bear no resemblance to the efforts of human force. Gravitation is one of the great mysteries of the universe, an evidence of high power : but it does not seem to imply an effort, and we possess nothing as a subject of comparison, so as to estimate the kind of power exerted : while I have also had occasion to say of it, elsewhere, all that can be deduced, under the general objects of this work. The falling of a body to the earth is so familiar, and appears to be so pure a necessity, that the notion of power cannot be impressed by any reference to it. It is in the centrifugal motions or forces, therefore, viewed as being originally tangential or rectilinear, and as being consequences of one impulse, that we must seek for the facts by which the notion of great power is to be conveyed and enforced ; because these are the only ones which we can compare to the effects of human power or effort. Thus to separate the objects of one science, may not be a scientific proceeding under “astronomy :” but it is my business to be definite for the purpose in view ; as that is, not to follow the order of science, but to convey intelligible notions

of the Deity, through such evidences of His attributes as all can understand.

Having thus stated the grounds of proceeding here adopted, I may commence with that which relates to the quantity of matter in the universe, or the magnitudes of the celestial bodies. I need not, however, detail all these sizes and numbers and spaces, accurately, nor state everything which belongs to the science of astronomy in this respect ; since, while it would be superfluous for my purpose, these things are to be found in every school-book. I have also preferred figures to words, in expressing numbers : unwillingly adopting even the word million. It may be true, that this term conveys no definite idea, though stated in figures ; since a thousand scarcely does this, in either case. Yet words effect less than figures ; especially in the higher numbers. A nonillion is scarcely more than a million, to our conceptions, powerless as the least term is ; and though in a lower point of this scale of useless words, we have a general notion that a billion must be much more than a million, from the habitual relation of one and two, there is no one who can conceive the real difference between those numbers. Yet a long series of zeros produces somewhat of the required effect on the imagination : the eye can see what is vainly presented to the ear ; and though it is not the truth, the object is attained in at least a superior degree, since it is the imagination which is to be influenced. Hence also the convenience of frequent comparisons with known sizes and distances and velocities, whatever air of vulgarity these may sometimes carry : since, without this, everything becomes general, and ceases to make any impression.

It is also the business of the reader to think for him-

self. This may not indeed be always easy : since it is an evil effect of the reading, or learning, of the present day, not to have exercised the powers of the mind : not even cultivating that memory which it purposes to furnish, since this is of little value without observation and reflection ; while, in reality, knowledge is not merely inapplicable without the power of generalization, but cannot be remembered, unless it is associated by some general principles. I may detail numbers and spaces and magnitudes ; but if the reader is content with that, I might as well have rested at the term Omnipotence. He must pause and meditate, and call up before his imagination, space after space, and number after number, even till he is checked by the confusion of his own mind. This is the way to think of the Deity in all : and its power has been demonstrated by its evil effects, since it is this which has generated fanatics and Yogis and Quietists, which has produced the insanity that fancied itself absorbed into the essence of the Deity.

The earth seems the most obvious basis of comparison ; but even this is a bulk that we cannot conceive, when we hear that it is 8000 miles in diameter, and 25,000 in circumference. We must begin at a lower point ; and it is best perhaps to commence by trying to approximate to a conception of its area, first. A square mile is a visible area : the earth contains 200,000,000 of these. This is an enormous space, when we consider how many common objects, trees, houses, or men, a square mile alone will contain. It is more difficult to find a sufficiently familiar and large cubical standard, whence to rise to some equivalent conception of its solid content. Yet they who have seen a mountain, and read of Teneriffe, can suppose it

a cubical mile of rock, since the truth is sufficiently near for the present purpose. And the earth contains 263,858,149,120 such masses: a bulk passing all conception. If, lastly, we take a ton as a tangible standard for its weight, that has been computed at 552,058,033,372,264,229,910, assuming its specific gravity at 5000 ounces for the cubic foot: a sum, which, from the unavoidable smallness of the standard, is quite incomprehensible.

This is an immense mass of matter to produce and collect and shape: but it is still so small, that it almost vanishes when brought near to what the solar system alone must contain. I may omit the moon altogether in this estimate, as an inappreciable quantity: and when a globe of 2180 miles in diameter would be as little missed out of the collected matter of the system as among the figures by which that must be expressed, it is this very nothingness which conveys the strongest impression of the enormous content of even this limited collection of spheres. All the eighteen moons might indeed be equally omitted, with thousands more such, were we to contemplate the great collections of suns and systems to which our own belongs; for they would not be as the heads of so many pins in the bulk of our own earth. Compared to the sun only, our moon is as a cricket ball in the mass of an Egyptian pyramid: a neglected, if not an insensible object in such a place. I use familiar references, not numerically true comparisons; for the effect is equal, and it is the effect which is desired. And as I need not reprint the common facts of every school-book, the reader will there find the bulks and measurements and weights of all the globes in our system; while if, from

these, he will himself compute the total quantity of matter, the impression will be greater than if he had found it stated here.

This indeed so far passes conception, that it is better to take the Sun alone, since there is a mode of making its magnitude comparatively intelligible. Its diameter exceeds considerably that of the orbit of the moon ; and this is a more appreciable idea than can be conveyed through the well-known figures by which it is expressed, because we can substitute a vision at least, capable of influencing the mind, through what is seen, if incapable of accurate estimation. We can form some sort of conception of the vault of the sky as measured by the moon, and can further imagine this to be a hemisphere of the sun, by conceiving ourselves placed in its centre. If we then imagine the entire sphere of solid matter, of stone or iron, we shall have made at least some approximation towards appreciating this enormous mass of matter, as in this way also we can more easily extend our conceptions to the whole of the solar system and to other systems.

I may attempt to convey an impression of the space of our own system, in the same manner, as a basis for that utterly unassignable and incomprehensible one which the visible universe occupies. The distance of the moon from ourselves is the smallest appreciable measure which I can here use as the standard of comparison ; and that distance is 240,000 miles : it is 600 times the distance between London and Edinburgh. Yet this is almost forgotten when we reflect that our distance from the Sun is 95,000,000 of miles : and it is scarcely a sensible quantity in the 1,800,000,000 which intervene between the Sun and Uranus. And even this is but half

the diameter of the circle which bounds this planetary area : while he who desires to know what that area is, may compute it in two minutes ; as he ought, that he may feel what it is.

These distances, this space, has long passed all comprehension, under the standard from which I commenced. We must attempt to conceive the greater ones through motion and time. The motion of a cannon ball is the usual standard of comparison in this case, and it is the best that we can produce. The initial velocity, for even a second, is seldom a thousand miles in an hour ; but taking this as a convenient round number for the whole, it would require more than four hundred years for such a ball to traverse the diameter of the circle in question. If this is an incomprehensible space, it is as nothing to that which our system must occupy, did we add but the cometary ranges, and not all of the incredible vacuity which lies between the solar machine and the next in place of those which unite to form the entire celestial mechanism.

Thus at least must the reader attempt to conceive the mass of matter and the extent of space which our own system, an inappreciable weight and an unassignable point in the great universe, includes and occupies. Yet the task which his imagination has to perform, is but commenced. If however I borrow the next step from astronomers, it must be with the reservation that the assigned dimensions cannot command assent, inasmuch as their means of measurement are inadequate for such computations. Like all other sciences, this has its hypotheses and its dreams ; while much more apt to pass current, from the willingness of the multitude to believe those, who, to the imagined mysteries of mathe-

mathematical demonstration, add the authority commonly attached to a science considered inapproachable by ordinary men. The well-known bright star in Lyra is deemed the sun of the nearest system to our own, and its diameter has been said to be three thousand times greater than that of our sun. It should therefore possess one of 2,659,000,000 of miles, being three-fourths of the orbit of Uranus : while, according to analogy, its planetary attendants should be of a proportionate bulk. Before such a mass of matter, the earth becomes a nonentity in the universe : but I need not dwell on what is doubtful, for enough yet remains, respecting which there is no doubt. The task of comparison is indeed scarcely begun : did the reader even admit this computation, all is but the point, the pin's head, which he has so often pursued as a mountain and left behind as a nullity : and when he has begun again from that once incomprehensible which has now become a contemptible atom, it is but to reject once more what he was astonished at before he had reached it ; again to begin, and again to reject, and thus to be beginning afresh for ever.

There are a thousand stars seen by the naked eye, and each of those is the centre of a planetary system. It has been computed that 100,000,000, might be seen by the telescope, were they explored. But the truth is of little moment in this case, when the least numbers are more than sufficient to confound all the powers of the imagination. The reader may proceed from that mass and bulk which he has already found, and add to it a hundred, or a thousand, or multiply it by ten, by a thousand, by a million, or by fifty or a hundred millions. It is all indifferent : begin where he may, end

where he may, he must begin again, and again proceed; for when he has at last passed all which has so long since passed his conceptions, he may still multiply all this, all the numbers of all the suns and planets, all the bulk of matter of that great celestial territory, the Milky Way, in which our atom of a solar system is an insensible point, by the 250 further nebulae which astronomers have ascertained. This he must do: since in each of these there are millions of suns, tens of millions of planets; each star a sun, perhaps a Lyra or a Sirius in dimensions, with all its attendant numbers and bulks of planetary, and, probably also, of cometary bodies.

Does he suppose that he has even yet finished his task? he has not finished as long as there is still a nebula which has not been measured and numbered, as, of these, there are yet hundreds of thousands. And what even will he venture to decide of that which telescopes may yet effect? Knowing what their progress has been, knowing that there is nothing wanting but to surmount a very few chemical and mechanical difficulties, that we may gain an insight into the universe of systems of nebula, far beyond all that we have hitherto attained. Even then, the most common reflection must tell him, that the limit is but that of our own vision. He will scarcely be so thoughtless as to suppose that man's eye is the centre of the universe, the regulator of space and its bounds; that all this expanse of orbs was appointed and placed with a reference to that eye, that nothing more remains to be seen, that nothing further exists when once the radius of that circle which it can command is passed. He will not at least think thus, when he finds that this eye is continually extending its

range, and that its limits are never more than those of its sensibility under new optical aids. He who can be so inconsiderate, is the man who supposes that all this universe was created for him alone, that the atom, himself and his races, was that to which the Creator extended His chief regards when He said to unbounded space, Be thou filled. Unbounded space assuredly : for where are the limits of the universe to be fixed, where are there not the congregations of globes, the congregations of systems of globes, and of systems on systems, which we have already seen ?

Can man conceive that there is a star in the remotest part of the Milky Way where he would not see around him what he now sees, an unterminated collection of stars and systems ? Will he transfer himself in imagination to the remotest nebula which he can see, to the remotest part of that remotest nebula, extended in itself as is the most distant star in the Milky Way from the earth, and, even then, believe that he is at the edge of the universe of orbs, that all beyond him is empty space ? This, he cannot suppose. The universe cannot be thus bounded : his metaphysical reasonings have told him that it cannot ; but the very facts are now brought before him, he sees into the boundless universe, into the depth of that incomprehensible machinery which is extended for ever and ever. And in what way now will he betake himself to conceive the quantity of all this matter ?

After such contemplations as this, it is almost superfluous to bring the reader back to closer conceptions of the nature and reality of these distances, of the unspeakable vastness of that space which includes even the least portion of this unbounded sphere of worlds on

worlds. If he will take the diameter of the earth's orbit as the point of his departure, it will form a measure, such as it is, for the next step which astronomical observation enables him to make. But that step is the first and the last. If the space required for the independence of our system cannot be known, astronomy fancies that it has ascertained the distance between our Sun and a Lyrae to be 20,159,665,000,000 of miles. Let him, then, who would endeavour to think of the extent of the visible space around him, remember that it is a collection of the added distances from star to star, and then accumulate on accumulation that which separates the sun from Lyra: if indeed then, any better than before, he can attain to conceive the dimensions of that sphere of space which includes all, from our own place to the remotest star of the last visible nebula.

But I can do no more for the reader who desires to comprehend the power which performed all this. That Power—is it not truly without bounds?—first created all this incomprehensible mass of matter by an act of its will: that Power separated it into globes, and placed those globes as it shaped them, not casually, not thoughtlessly, throughout this incomprehensible space, but each in its due and exact situation, and each in its appropriate and computed size. That Power again collected those globes into mutually dependent groups, and those groups it grouped again: perhaps again repeating this, to form the great machine which it had contemplated when as yet nothing existed but Itself; He who was before all, HE WHO IS.

In what manner did He do all this? Again we must have recourse to the same standards of conception derived from our own powers and actions. Did He first

produce a reservoir of matter, and then shape and dispose the parts? He must have moved from place to place, were He like us, a local Being; however omnipotent in action. Did he create the matter where He also willed to place it? a local Being must even then have moved throughout this incomprehensible space. Could we suppose the Deity thus limited, even this would be power beyond conception: His universal presence at all moments is not more difficult to conceive. His eternal omnipresence is not therefore a mere metaphysical inference, but, to adopt such a term, a physical necessity: and of His “immensity” the reader may now, possibly form that conception which no metaphysical reasonings could ever have given him.

But, as yet, I have turned the reader’s attention on matter and space only: on the incomprehensible quantity of matter in the universe, and the inconceivable distances by which the parts are separated. I have spoken but of bodies at rest: the orbs of the celestial machine are bodies in motion. And thus arises that further view of the Divine power which I already indicated.

I formerly observed, that it is the tangential forces alone which concern us under this inquiry. It is indeed an assumption that those bodies were once at rest, and were afterwards put into motion. But while it is a convenient one for the present purpose, so is it a prime or instinctive belief, of which we cannot divest ourselves. The state of rest appears to us the natural condition of all matter; its motion implies action, and we know, or see, that action must commence: there must be a cause, and that cause, whatever may be the intermediate one, the power or will of a living being. But, as the Deity is here concerned, it is indifferent for the present view,

whether He first created a globe and then put it into motion, or whether both acts were simultaneous. Large masses of matter are in motion: they could not have moved themselves; and therefore they were moved by an external power, by a living Being; by the Deity.

It is our business then to attempt, in the same manner as before, to conceive what the quantity of this power is: it can easily be proved to be very great: and the same train of thought will, as easily, show that it must be illimitable. There are two modes of the centrifugal motion; the revolution of a globe round its axis, and its circulation round the general centre of gravitation of a system. It is here my business to consider each as the rectilineal motion to which they are reducible; but the former being superfluous for the present purpose, I may neglect it altogether.

To recur to the same human standard, we have a conception of our own force in the throwing of a ball; how small a weight is all that we can move, and with how small a velocity. By the greatest force that we can use, the elasticity of air, we can project an iron ball of fifty or a hundred pounds in weight, with a velocity which I may again assume at a thousand miles in an hour. But in the same time, the earth moves 68,000: it is like a cannon ball of the enormous weight which I already stated, moving with sixty-eight times the velocity.

To our minds, a second is so short an interval, that the ball is almost at both the extremities of four hundred yards at the same instant. But the earth is at both ends of a distance of twenty miles in that moment: or, if we could see it move, we should see it almost at once, at London and at Windsor. If such a weight, moving

with such a velocity, is scarcely to be conceived, what then was the power of the Hand which projected it? The utmost force of gunpowder is a zephyr.

Yet this is nothing. Such is the velocity of Mercury, that it would almost make the entire circuit of the Earth in a quarter of an hour; the journey to New South Wales in five minutes. Can we fancy a cannon ball as large as the moon fired to the Cape of Good Hope in five minutes? but it is almost indifferent what magnitudes or velocities we take, for all is equally surpassing conception. Jupiter is equal in weight to 1400 earths, and its velocity is 29,000 miles in an hour. This mass, He spanned it in the "hollow of His hand," and He launched it with that velocity. Thus has the psalmist taught us to speak. But His word, His will, performed all this, and more. To that mass of matter He said, Fly thus, and it flew.

Is it possible to add higher conceptions of force, of power, to that which is already inconceivable? The velocity of a Comet has been estimated at 880,000 miles in an hour: it is one that would carry this mass from London to York in a beat of the pulse. But what can even this be, when we consider the systems of the doubled and mutually revolving stars, if especially, as is to be supposed, they carry entire systems of planets round each other? I need not here name the periods of those whose times of revolution have been ascertained: it is sufficient to note, that in ξ Ursæ the motion is so rapid that it can be measured from month to month. Of the nature of these systems, it is true that we know nothing: but should we even suppose anything, I know not on what ground we can pretend to limit velocity more than space: since to us it is bounded

by our limited powers of conception respecting time. The Ptolemaic system was absurd, because it was unwise: who shall say that *Lyra* or *Sirius* might not have performed a circle round the earth in a year, had the Creator so chosen? True, it would have required an enormous retaining force of gravitation; but there are no limits to His power.

It is in vain to proceed with this subject where there are no grounds even to guide the imagination through those motions and velocities which must exist if the systems in the universe are performing groups of circles round distinct centres of gravity, and thus finally round a common centre; as modern astronomy has supposed. And if any one desires to think, as has been idly enough suggested, that such a centre must be a mass of matter, bearing the same relation to those circulating systems as our sun does to its attendant planets, then indeed he has proposed a view of the quantity of matter in the universe, to which all that I have hitherto attempted to impress is as nothing. Yet let us not forget also, that it was not one system alone, not a thousand or a million of systems of bodies only, which the Deity thus moved at their creation, but that He thus put into motion every sphere of the inconceivable myriads that crowd the visible heavens, in all their magnitudes and places: and thus again, orbs beyond orbs, beyond all that is visible, all that can be inferred, all that can be conceived, everywhere throughout all boundless space. Is there any imagination that can so place itself as to see all these motions, all this mass of motion, all this multitude, and variety, and velocity, and extent of motion? Let that poet try: it is he who will conceive somewhat at least of the force which effected all this; something

of the Power which could say, I command; and saw it all done.

This is the Creator: this is the Power of God; and this is Omnipotence. This is the God who has been doubted; that is strange: who has been disputed or denied; that is still more strange. But this too is the God whom vain man thinks the God of petty man alone, whom he views as solely occupied on his vast and exclusive self and his all-important concerns. O ye ignorant as vain, and selfish as ignorant! Study Him in His works, that you may learn to know Him, and may learn to know yourselves for what you are. He is far more worthy of adoration, greater and wiser and better than all that you ever imagined or will conceive. Of His power you know nothing; you cannot comprehend the most minute portion of His wisdom; and He is, beyond all, the uttermost of your possible conceptions, bountiful and good, since for you and such as you has He done all this; for you and such as you does He govern all this, as He has governed it for millions of ages before you existed, and will govern it through inconceivable millions more when your atom of time is past.

I must now proceed to inquire of the Wisdom of the Deity in the construction of the celestial machinery; but this view must be limited to our own system, for, of the rest we can judge nothing. We cannot even show that wisdom has been exerted in the great universe, from the moment that we pass the territory of the Sun: we can but infer it through analogies, physical and moral, yet these are analogies by which we cannot be misled.

The first obvious view to be taken relates to the question of Design, as the proof of Intelligence: while

the proof of this becomes an answer to an hypothesis of chance, could an answer again be needed. The system of the Sun is a collection of bodies, the magnitudes and velocities of which are known, placed in definite relations of position towards each other; all moving in circles, or nearly such, round a point of rest; and all influencing each other's motions, through the gravitating force: the circles of the principal planets being performed round the sun, while some of these are attended by a second order of planets performing circles round them, and also carried onwards by them in their own circles. This is a very complicated problem to have executed: though I here omit the comets and the rings of Saturn. The original calculation required, was, so to apportion the sizes, or weights, the places, and the velocities of all these bodies, that the total collection of places and motions should be permanent, notwithstanding all those mutual influences, which, it is plain, must be for ever varying; as so many bodies, mutually gravitating towards each other, and with more or less force according to their varying proximities, change their relative positions. For this purpose, mathematics can show, that every weight of every body, and every place, and every direction and velocity, required to be determined, while they have also shown that such calculation has been made, by the great fact that the system is a permanent one. For the truth of this decision however, the general reader must trust to mathematicians, since the demonstrations cannot be made intelligible to any but him who does not require them, and can, with difficulty, be even indicated in popular language. Still, the result of those investigations may be stated in the following manner; pointing out, under the question of

chance, what might have been, and is not : whence the necessary inference of calculation, and therefore of design, follows.

The law of gravitation might have been different from what it is, in more modes than one : but there is not another that would have agreed with the numbers, weights, velocities, and distances of these bodies, so as to have preserved the necessary order. The relative weights of the sun and the planets might have been any other than what they are, and under infinite variety, while the existing law of gravitation was adopted : but there are no other than the actual weights which would have permitted this perfect and permanent mechanism ; as it was especially necessary that the weight of the sun should be very great, and that of the planets very small. The relative places of the several planets to the sun might have varied in a thousand ways ; yet there is but the existing order, again, through which the machine could have been the regular one that it is. As in the comets, the forms of the orbits might have been, in endless modes, different from what they are ; but the present are the only ones applicable to the great purposes of order and permanence : while, further, only one direction united to one velocity, where each of these might have infinitely varied, could have produced those forms. It was not necessary, for any other reason than that which has guided the whole of this choice among possibilities, that all the planets should have moved in one direction : but had some moved in an easterly one, and others in the reverse, that result for which all else has been so evidently calculated, would not have been attained. And again, with a central point of rest, there are uncountable lines in the spheres indicated by each

planetary circle, in any one of which any planet might have moved, as all might have moved in widely different ones, even to the meridional and equatorial. But mathematics can demonstrate, that there are but a few lines near the common equator whose plane cuts all these imaginary spheres, in which these bodies could have moved, so as to have preserved the order and durability of the machinery, while among these we find the actual inclinations of the ecliptics. Lastly, if the force of gravitation acts in proportion, inversely, to the squares of the distances of the bodies, as, under the other circumstances was necessary for the stability of the system, it was equally necessary that the periods of revolution in the several bodies should not be commensurable, and that the existing eccentricities should be small, as, further, that these variations should lie within narrow limits. The eccentricities are inconsiderable, and the elliptical orbits do not differ much from circles. And this is a law for the stability of the system. The orbit of any planet changes to a circle, but returns to the same form. Or, to state this in mathematical terms, the mass of the planet multiplied by the square of the eccentricity, multiplied again by the square root of the greater axis of the orbit, is a constant quantity; or, as one of these varies, so do the others, in such a manner, that the product is invariable; or whatever mutual actions the planets may exert on each other, this balance is never lost.

Here then are numerous necessities required to produce that peculiar end, a durable regularity, which we may fairly infer to have been the end in view, because it is attained through the accurate coincidence of so many different and independent circumstances. Every

one of these things might have been other than it actually is, in innumerable ways; and under such a multitude of entangled bearings, that, upon an hypothesis of chance, it is evident, even to ignorance, the actual result could not have existed. But the usual calculation of probabilities suffices to prove the impossibility of this having occurred under chance: as far at least as a ratio which, in common language, is almost that of infinity to one, can serve to infer such an impossibility. The conclusion is not less complete and striking than in the simple case of the Peacock's feather, formerly brought forward for the same purpose. In another view, every one of these circumstances was of arbitrary choice, before they existed; while having all coincided for the production of an obviously useful end, the intention, and consequently the Designer is proved. And it is scarcely needful to say, that He is equally proved by the mathematical calculations required to plan all this before it was executed. The race of man, labouring since the creation, and with all the facts before it, has now but barely ascertained what the requisite calculations were. It is not for him at least who has laboured through all this, to doubt the mathematical knowledge which has thus calculated, long before he could discover what the calculations were. A La Place does not doubt this of a Newton: did he do so, he must deny his own understanding: what then if it be doubted, because it is to the Creator of Newton and La Place that we attribute this knowledge?

The proofs of the intelligence or wisdom of the Deity are now also, therefore, equally before us. The planetary system has been wisely planned and executed, because it serves its obvious purpose perfectly; and it

has been wisely executed, because it is executed in a simple manner ; under simple original arrangements in the choice of weights and places and motions, balanced and maintained by a simple law for gravitation. And the end, or final cause, is naturally inferred to be the permanence, or at least the permanent regularity of the system ; as I have just said, and as mathematicians can now show, long as they laboured before they could prove that such was the result. And I have noted elsewhere, that till these researches had been carried thus far, this inference could not have been made ; as it was therefore concluded by Newton, that the Hand which constructed this machine must also occasionally interfere to repair it. And thus perhaps might we draw the much wider conclusion, that whenever we do not discover analogous perfectness for ends, in other parts of Creation, the cause lies in the imperfection of our knowledge. What mathematics have at length inferred, might perhaps have been equally inferred by all the sciences, had they been equally known ; as it possibly may hereafter. But the science of mechanics is a simple one, and has naturally gained the start in this inference ; as that is probably all. We ought to infer, metaphysically, that the works of a perfect Being must be perfect, and that when we judge otherwise, it is because we do not know the ends : while it is of importance that we can thus bring a fact in evidence, though but one, to prove the prior conclusion.

But the conclusion respecting the permanence of the planetary system may be carried too far, because it would infer an eternity : and thus have some mathematicians concluded on a necessary eternity in the future ; inferring, moreover, the same as to the past. This last

speculation I have examined elsewhere, (c. 5) and as to a future eternity, I have shown, in speaking of chemistry, that they have entirely overlooked this great force in nature; drawing their conclusions from their own science alone. But though chemistry had not existed, it would be rash, at least, to infer such an eternity; since, under the admission of a Deity, it would imply that He who arranged this system could not destroy it, which is absurd, or would not, which is presumptuous.

The just conclusion to be drawn from the steady order of the planetary system, is this: that it is simply an act of wisdom, leading to no ulterior conclusions as to an absolute permanence. It has been created mechanically unchangeable, as far as it is so, because, had it been otherwise, it would have acted wrong during its existence, and, as mathematics show, might have acted so wrong during a long existence, as to have defeated its objects; which would have been unwise. We may therefore still suppose, that a definite period of existence has been allotted to it; although, during that period, every action is that of a permanent or eternal system. It is surprising that Mr. Playfair, that any mathematician, should have supposed arguments for an eternity deducible from the fact of a steady order; since the reasoning is as bad in mathematics as it is in logic. A machine intended for an end must be made so as to answer that end. The analogy of the animal system is also as opposite as it is simple. A physiologist acquainted with the anatomy and actions of such a machine, and knowing of it nothing more than the regularity with which every thing proceeds through a few years of their permanent order and vigour, would determine it to be eternal. That regularity was necessary

for the purposes in view : but it was required for a time only ; and an end is appointed to it.

But if I have hitherto followed mathematicians, I have granted more than they can prove, in asserting the permanent regularity of the solar system, under their own science. It is true, that as far as the mutual influences of the planets are concerned, the irregularities of their motions, whether comprised in short or long periods, secular or periodical, are oscillatory, or arrive at certain known maxima, again to diminish, and to recommence the same round ; and it is also true, arguing on the same exclusive grounds, that the year is invariable, because the greater axis of a planetary orbit, and the periodical time, never change. But when the far more numerous cometary bodies are excluded from these computations, whether because no actual disturbances produced by them are discoverable in the registers of astronomy, or because it is assumed that they can produce no effect, from their short residence within or near the planetary area, or because astronomers are glad to exclude what they know not how to manage, they are deciding on a future, at least, of which they can know nothing. We may smile at the popular fear of comets ; but he will be a bold mathematician who shall say that some of them shall not, at some day, change the order of the planetary motions, or that even such results have not been prepared in the original calculation of their own motions and that of the entire solar system. And if we are desired to believe that the four small planets are the produce of some collision of this nature, they at least who think thus, should no longer argue for a permanent system, far less for an eternal one.

Let us admire the order of the planetary system, without drawing false conclusions from it. That order has been established, and has been rendered permanent as long as the Creator shall so will, under a complication of bodies and positions and motions and velocities and influences, which once appeared to us as hopeless a problem to solve, as we believed the preservation of a permanent order under such circumstances to be impossible. It has been effected by a system of compensations, which, the more we study them, the more wonderful they appear: displaying a profundity and accuracy of mathematical knowledge which we know how to appreciate, because of the extreme rarity of those powers in ourselves which have at length ascertained what it was. How could this have ever been doubted? Yet if the pious metaphysicians never did doubt it, it is still satisfactory to find that it can be proved by physical facts, almost by our senses themselves: as it was also the business of this work thus to prove it. In most other cases of physics, our proofs are imperfect, because our knowledge is defective. On this particular subject, it is more perfect than on any other: and thus do we prove that absolute intelligence and wisdom on the part of the Deity, which, before that, we had only believed: while proving it on this one point, we the more easily conclude that it is the same on every other, and that the deficiencies of our proofs must be sought in our own ignorance. And if the celestial mechanism is of such value on the subject of these attributes as well as on that of power, whence could a writer on natural theology set light by "astronomy," as of inconvenient or imperfect application for his purposes? Sir W. Drummond, indeed, considers that the "Newtonian

system" tends to atheism. It is really very difficult to foresee what men will not say, when they write more than they reflect. From this and similar accusations, no one indeed seems to be safe; it is sufficient that he thinks differently from another, even on points the most unimportant.

I consider that the subject before us is still widely applicable to the proofs of the goodness of the Deity, and shall therefore proceed to some remarks on this subject. I have already had occasion to say, that the planetary bodies could have been created for no other purpose than to be the habitations of animals: except for the happiness which these derive from existence, we can see no end in view. If this is the exertion of beneficence, the magnitude of that beneficence can now be estimated more justly, from the extent of the efforts of power and wisdom which have been directed to this sole end, and from the collective immensity of the territories provided for the happiness of animals, throughout an universe which we may safely consider as without bounds. If this is but a broad and general view of the Divine beneficence under this subject, former writers have indulged far more widely in details to the same end; though these are often superfluous statements, or identical propositions. It seems idle to say that the planets need not have had diurnal motions, and that these are special acts of beneficence. The beneficence of this arrangement is unquestionable; but as the planets were created for the use of animals, the diurnal rotation cannot be presumed absent, without also presuming on a plan for an end, and that end defeated through an imperfection in the plan. It is therefore a necessity involved in the general beneficent design. And the com-

bination of the obliquity of the axis with the annual motion ought rather to be noted as an act of contrivance or wisdom, though intended for the same beneficent ends. In the case of the diurnal rotation, as I had formerly occasion to remark, the contrivance should rather be sought in the adaptation than in the mechanical arrangement. The nervous system of animals has been appointed to suit a diurnal rotation; and had that rotation been any other, we cannot doubt that their constitutions would have varied accordingly. The inference is the same, if we reason from the necessity of light to mutual communication.

The case of the planetary moons, however, and of Saturn's rings, is of a different nature; since we may view these as decided supererogations in the system, intended for as decided an end, in conducing to the happiness of animals, beyond the general plan for their enjoyments or uses. I must not indeed use the word supererogation as a mathematician; since the presence or absence of these bodies is not a matter of indifference to the order and stability of the planetary system. But that stability might have been effected without them, as it has been planned to include them; so that the moral conclusion is still the same. That they were not necessary to the planets as mere portions of the solar machine, is proved by their absence from some: though, even under the present view, we cannot conjecture why Mars should want what we possess, or why Venus also should not have its nocturnal luminary. And thus we may safely conclude, that the creation of our moon, at least, was an additional act of beneficence towards ourselves, and consequently as pure a one as can well be selected.

But I cannot terminate this chapter without some remarks on the often discussed question of the plurality of worlds: ill discussed, I may safely say, even by the well-known and celebrated names that have written on it.

Nothing but the most grovelling notions of the universe and its Creator, can suppose that this little earth is the only habitation appointed for life. It is indeed the natural conclusion of ignorance, as it is then pardonable: but it is not pardonable at the present day, in the thousands who might know better and ought to think more justly of the Deity. It is worse than unpardonable, where it is the result of narrow-mindedness and vanity, in those who never think of the Deity except as occupied about themselves, nor of themselves but as His sole care. And it is too often an evil consequence, I might almost say a sinful one, of narrow and peculiar religious views; of an exclusive adhesion to such parts of the revealed word of God as can be made the foundation of special hypotheses in religion; false as the hypotheses of human philosophy, because they are partial views of truth, not The Truth. These are the views which, as I remarked in the first chapter of this work, make a Deity of their own; which see God but as the petty judge of a petty kingdom, ever occupied in punishing and pardoning, ever thinking of man alone, and perhaps of the worst among men; or, worse even than this, the Parent whom no effort of goodness can please, or the Creator who purposely produced vicious beings for the very end of condemnation. If this, to give it the most gentle term, is irreligion even beyond atheism, it is not religion that would contemplate the Deity as the God of men alone, and thus

attempt to rob Him of His attributes. There may indeed be no cure for such conditions of mind: but it should be sought in juster ideas of the Great and Good Parent of an universe of beings: of the incomprehensibly Good, of the contriver and giver of happiness to more myriads, at all instants, than there could be sands condensed in the globe of the earth; not the angry judge of evil only, ever occupied in remedying a little evil in a little spot, which, compared to that universe which is for ever and hourly His care, is not what one sand is to the whole earth.

And why should we not try to form some conception of this mass of life, this number of lives; of this immensity of goodness? as we have already attempted to estimate the immensity of His power. The plurality of the mere celestial systems involved in the great machine of the universe, is but a subsidiary question, as is that of the planetary bodies which they may include; while they bear on nothing but the attribute of power. And though we speak of a plurality of inhabited planets, it makes no impression on the mind, especially under the manner in which this subject has generally been treated. It is as when we speak of Omnipotence, and do not inquire of the details of this unbounded power. If we would feel what the plurality of inhabited worlds truly means, it is of the number of lives that we must learn to think, as I have endeavoured to make the reader think of the numbers of the great bodies of the universe. Even the inference as to other inhabited planets in our own system, or in any, or all, systems, has hitherto been but an analogical conclusion: it has been a moral inference from the character of the Deity. A physical writer, he who attempts to prove the conduct of the

Creator from the visible universe, ought to produce physical reasons for such an inference ; as, with this I shall commence.

I have shown (c. 37) that the universe of orbs might exist and proceed as it now does, on the laws of mechanics alone: as a machine consisting of abstract, or neutral matter, governed through special motions. But I have also shown, that mechanics do not constitute the sole power in nature, that the machine is not the universe. I have demonstrated that chemistry is a great power in our own earth, and have proved its existence throughout every orb, to the uttermost known regions of space. I have further shown, that its great purpose on our earth, if not its sole one, is to produce organizations for the uses of life, or to construct living machines, to feel and be happy. And if the general result is, that whatever other purposes Chemistry may serve, they all conduce, more or less directly, to the ends of life, it is a safe inference, that existing throughout the entire universe, it exists there for life, and that life therefore is universally distributed. The same conclusion follows from the utility of light to animals, and its inutility to all purposes not referable to them ; while, to the universality of light, I may add the equal universality of heat. There ought to be inhabitants wherever there are light and heat ; and these are everywhere throughout boundless space.

These great physical facts apply to the entire universe, under this question : those of astronomy give us proofs that apply only to our own system. But if the rotation of the earth is a mechanical contrivance purely for the sake of animals, the same secondary motions occur in every planet ; whence the obvious conclusion,

that every planet is inhabited by animal life. The same inference is deducible from the planetary moons; since, as I have already said, these are supererogations to the general machine; as it also is from the rings of Saturn. I need not speculate on the probability of inhabitants in these different subsidiary bodies: having their uses for the purposes of life already, such a condition is not necessary, under these moral views; and I need not say, that it was no greater effort for the Deity to create a moon than a gnat, since everything, equally, is a simple act of His will. The same remark applies to the Sun, which some philosophers have supposed so constructed as to be capable of inhabitants: and if objections have been made to the possibility of such a condition in Mercury, our present knowledge of light and heat assures us that they are groundless.

These are the additional considerations, in favour of a plurality of inhabited worlds, which we derive from the mechanical facts of our own systems: but as far as they may apply to the universe at large, they tend only to analogical reasonings. Utility to animals, goodness, is the purpose of all that we see in the fundamental arrangements of our own system; especially seeing the application in the subsidiary ones: and thence I may argue that the subsidiary are attached to the fundamental ones, throughout the whole universe, and that the end is the same; or, at least, that where the great purpose is so clearly shown by these subsidiary arrangements and their results, it must exist everywhere. We can conceive no purpose in a planetary globe that is not inhabited, none in the myriads that must pervade all space. There is no purpose in the myriads of suns by which it is filled, if there are no planets: but there is

also no purpose in those uncountable luminous centres, if these planets have no inhabitants. - They are useless to us, and useless to all the possible inhabitants of the solar planets: there are even myriads unseen. They are not created by the Deity for His own contemplation: His ideas suffice to Himself. Therefore is the entire universe an universe of planets as well as suns, and those planets are inhabited. This is the argument, and, with the former, derived from the great and all pervading powers which rule in the universe, it constitutes the jointly physical and moral argument for the plurality of inhabited worlds, the universality of life.

If that has not yet been attempted, I do not see now, why we may not venture to form conjectures as to the nature of the beings which inhabit these planets; general and slender as they must necessarily be. It is true, that the power of the Creator is beyond our conceptions, that He may have produced a variety of being, of which we cannot form the slightest idea. Still, we are not excluded from attempting certain generalizations, founded on those facts in the universe which we can ascertain. The mechanical differences may be immense: yet there seem to be some broad physiological features by which the whole should be united. Thus also should there be some leading, or common, moral resemblances: arguing partly from the physical facts, and partly from the character of the Deity Himself.

Light being universal, its uses must be similar to all animated beings throughout the solar system, in the first place, and therefore also, throughout the universe: as, further, without vision, we cannot conceive an animal connected with any objects around it that are not in contact. Hence therefore we may commence by in-

ferring similar organs of vision ; eyes. There are other planets in our own system which possess atmospheres ; while, knowing that chemistry is universal, we may infer this arrangement far more widely, if not universally. Hence are implied lungs, of some kind, and, with those, a circulation ; as, by consequence, a fundamental structure not essentially differing from those which we know. The equal consequence, if this view be just, must be a supply of food, and thence, plants ; as, in variety of surface and of exposure to the sun, is implied a variety of those : a vegetable creation under a general analogy to our own, however differing in the particulars. And on this subject, the following fact also is deserving of notice. Such is the law of internal attraction in a sphere, that in Jupiter, though so far exceeding the earth in bulk and in gravitating power, the force of attraction at the surface exceeds that on the earth by less than one and a half only, while in Saturn it is but one quarter greater. It is plain, that very slight variations in tenacity and muscular power, would form perfect compensations in both cases ; as, in the latter, the needful difference would be far less than occurs between hundreds of different animals among ourselves. Any one can easily pursue these conjectures farther than I shall here endeavour ; in concluding, for example, that an atmosphere implies birds, and water, fishes : it suffices that I have furnished the grounds of judgment.

But as light and heat, alone, imply a nervous system, sensations and objects of sense, with consequent action, pleasure, together with pain of course, is also implied ; as the former is safely assumed from the final cause. And as we must thus also infer desires and will, we have the grounds for presuming on certain moral dis-

positions or characters, from purely physical considerations, and independently of any reference to the moral character of the Deity. Thus also ought we to deduce evil and imperfection, as we at least view these : since they are inseparable, to our utmost conceptions, both from moral and physical arrangements. And thus also, mortality and reproduction ; the more especially when we take into consideration the great power, chemistry : since in these bodies, as in the earth, this ought to be the agent for constructing these living machineries. Angelic natures, as we conceive of those, are excluded from all these considerations : since of no form of existence unconnected with a material machinery, can we form any other idea than the same vague one which we have of the Deity Himself.

Are these inferences wild or fantastic ? We conclude more widely than this in morals, nay, often in physics, every day, and on grounds as small. The novelty and magnitude of the conclusion may render it alarming : but that is all ; it is, still, one of the analogical reasonings in daily use. May it not rather be viewed as a magnificent generalization, and another inference respecting that essential simplicity which pervades the plans of the Creator, whatever the varieties in the details or the execution may be ? The planetary machines, throughout the universe, are based on a few simple mechanical principles, and the machines themselves are similar, if not identical. The broad principles of animal and vegetable machines may be as simple and universal : in many things, they can scarcely be otherwise, unless there be a mathematical science of which we know nothing, and utterly different from that which we do know. The variety of detail is great, to our

own knowledge: it may be far greater, or unbounded as the universe itself; and yet all that is essential may remain. Chemistry is but one power everywhere; as light and heat are all-pervading spirits, souls common to the entire universe. Life, by its very nature, can be but one thing; the mode of its attachment to matter, and its power over chemistry, for construction, but one; and wherefore then may not this simplicity of principle pervade all living beings?

But of this, enough: he who has more space, may expand this view of the "plurality of worlds." The great question which yet concerns the beneficence of the Deity, is the multiplicity of this life, the numbers of lives existing, to feel, to will, and to enjoy: for that multiplicity is the measure of the magnitude of His beneficence; of that universal and boundless beneficence, for which theology has not invented the single term which it has contrived for so many of His attributes.

What number of beings, formed to enjoy, and enjoying, does that universe which I have already taught the reader to measure, contain? The first aspect of this question is appalling: the least chance of a possible conception respecting it, seems hopeless, at the first glance: yet is that very hopelessness, if rightly considered, the best answer, the very effect that I should desire to produce. But there are not many who have so cultivated their powers as to feel what he of intense imagination may; and, for them, I must again have recourse to the process of addition: to numbers. And the process is the same as before: it is to take a single animal, at one instant, in its numbers, on a known territory or space, as the basis: it is to add space to space, and numbers to numbers: it is, again, to take other

numbers, and again to proceed through spaces: and thus, till numbers and spaces, long vanished from the mental eye, have proceeded beyond the bounds of the imagination, even to its disturbance.

At every instant, the earth contains 800,000,000 of men; taking the usual conjecture, where all would be equally valid for the present purpose. Presuming on some analogous animal and an analogous globe, the surface of Venus contains as many more. Will the reader take the areas of all the planets of our system, and fill each planet with corresponding numbers? for, why should I give him the facts, when, at the next step, we are utterly lost. He has but just read of the myriads of solar orbs visible in the creation: he may multiply them by ten, or by any other number that he pleases, for the inhabited planets of the universe; and again he must multiply them by the number of men in the earth, at least. He was lost at the first step, and can lose himself no further. A single system was too much for his imagination, even under a single animal; and that animal not one of more than half a million of kinds inhabiting the earth, while also not containing one individual, where a single other species contains thousands of millions. What would ten systems be, what the Milky Way with its hundreds of thousands of associated systems, what the thousands of nebulae which he can see, each containing tens of thousands of planets, and what, lastly, all that he has not yet seen beyond those? No one can conceive the bare numbers of the planets themselves: yet must he multiply them by 800,000,000, as the first step towards estimating their total population, while selecting this number also from a single terrestrial species, of a very limited extent.

But could he even persuade himself that he has done, or conceived, this, he has done nothing. He may reject this whole sum of animals, and he would not miss it in the great total. Miss it then? he would not miss it at the very next step he chooses to take. Arithmetic would not miss man among the animals of the universe, had he occupied every planet, and been exterminated throughout the whole: the earth itself would not miss him in the number that would express its gnats alone: man, that important being, of which each individual thinks that all was made for him, and every thing subservient to his pleasures.

We may take these gnats themselves, as a further step towards conceiving the population of the universe, if there is any one who can still pursue this bewildering inquiry. There are hundreds of millions in hourly existence, for every man which the earth bears. What numbers will he conceive Jupiter to contain, what the solar system, what the system of the Milky Way? to go no further. He has seen a hundred millions on a river's bank, in one hour of a summer's evening: each animal atom a life, a will, a seat of desires and a source of happiness. Will he imagine such spaces so filled, throughout the solar system; throughout a single nebula, all the nebulae, throughout all the boundless universe? I have formerly shown him animals, of which thousands but equal a grain of sand, and I have shown him that his own planet is filled with these, and with millions on millions more, like these, even through the depths of the ocean. Will he conceive that millions of such grains are each of them, the measure of but a thousand such lives, in every planet of every sun that he can see, to the last star, in every planet of all those suns which

he sees but as a collected and faint mist, to the uttermost bounds of assignable space, and still beyond all that, for ever and ever.

Yet the scale and basis of all this computation is far indeed from including all the inhabitants of the earth, at even one moment. All that I have named might vanish from it, and it would still afford the basis of such a computation; any new one, successive ones, to thousands and hundreds of thousands of times, might be blotted out, yet the difference in the great result would be insensible; such is the living universe, such the utterly inconceivable numbers of the living beings by which it is at every moment inhabited. Let the reader reflect for himself, since the writer can do no more.

And this is the Universe of life: an universe filled with the goodness of the Deity to His creatures, with goodness multiplied by myriads of millions more than all which I have, not quite vainly perhaps, attempted to bring before the imagination: for towards each individual of all those overwhelming numbers, a special act of goodness has been manifested, and by an act as special: as over each one of all, He exerts a perpetual care. Is not this also to conceive His everpresence, everywhere; His ever watchful care and government, everywhere, the division, the multiplication, the extent of His cares, over all this immensity of space and numbers? And is it not also to contemplate His providence, as we have never yet been called on to view it? It is all this, and more: far more.

So far more, so incalculably greater is all this goodness and all this care, that although we should conceive them to cease, for a year, a century, ten centuries, though all the immensity of being in the vast universe should

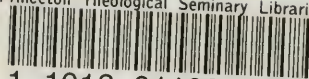
cease to exist through such periods, and more, it would not make a sensible blank in the total sum of the beneficence of the Deity. This is indeed the infinite, as far as we can ever conceive of infinitude : when we can for ever remove from an imagined mass or imagined numbers, whatever mass and numbers we please, and when the sum is still, for ever and ever, but the same to our apprehensions. All that is, now, has been from all time ; and all will thus be, for all time. He alone knows till when, if it is not to be for all the future, for all eternity. What have been the numbers of one animal during even the few past years of the earth, and what will these be in the future ? What have these been for all the animals of the earth alone ; and what then for every animal in every planet of the incomprehensible universe. But what also for all that shall be, through a future without termination and a space without bounds ? The total number of united existences throughout the entire universe, in any year, in any century, in any ten centuries, either, all, equally, are but an unit among the numbers that have been and shall be. It is the incomprehensible, multiplied for ever by the incomprehensible : it is to pile numbers on numbers, and time on time, and spaces on spaces, throughout an eternity, and still to find no end : no end of the individual acts of the goodness of God, of His individual acts of creation, of His individual acts of care for every one of those lives which He for ever creates and preserves, that they may enjoy.

And this is He Who Is : God, the creator of all and the preserver of all ; God, the Father of all. This is His creative power, and His wisdom, and His goodness, and His immensity, and His omniscience, and His

omnipresence. This is He whom we can at length see in His own universe, and yet, of whom we still see not the smallest portion. Look at what He does for one animal, one life; He has done it for all that exist, He did it for all that ever existed, He will do it for all that ever shall exist. Learn to think of Him thus: and thus will you learn to think justly of yourselves and of your relations to Him. Learn to know Him in what you can see, that you may know His ways; His character, Himself, in what you cannot see. Learn Him, who, if He cares not for you alone, cares for you as for every thing which He has created, and whose care for you is still the same as if you were the only existence. But learn to know Him aright: for He is good, and wise, and powerful, beyond all that you have ever conceived: the powerful beyond all power, the wise without limits, and, beyond all our thoughts of goodness, The Good.

END OF VOL. II.

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